Princeton Instruments

MicroMAX System

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Table of Contents

Chapter 1 Introduction 9

Introduction 9
MicroMAX System Components 9
Overview 9
Camera 9
Controller 10
Applications 11
Computer Requirements 11
About this Manual 12
Manual Organization 12
Safety Related Symbols Used in This Manual 13
Environmental Conditions 13
Grounding and Safety 13
Precautions 14
Repairs 14
Cleaning 14
Camera and Controller 14
Optical Surfaces 14
Roper Scientific Customer Service 14

Chapter 2 Installation Overview 15

Chapter 3 System Setup 17

Unpacking the System 17
Checking the Equipment and Parts Inventory 17
Power Requirements 18
Verifying Controller Voltage Setting 18
Mounting the Camera 19
General 19
Mounting the Lens 19
Mounting to a Microscope 20
Installing the Application Software 24
Drivers 24
Installing the Interface Card 24
Connecting the TAXI (Controller-Computer) Cable 25
Connecting the Detector-Controller Cable or the Camera Power/Camera Signal Cables 25

Chapter 4 Operation 27

Introduction 27
EMF and Xenon or Hg Arc Lamps 27
Vacuum 27
Cooling 27
Setting the Temperature 28
Temperature Stabilization 28
Baseline Signal 28
Imaging Field of View 29
RS-170 or CCIR Video 29
First Light 31
Cabling 32
Getting Started 33
Setting the Parameters 33
Focusing 34
Acquiring Data 36
Summary 36

Chapter 5 Timing Modes 37

Full Speed or Safe Mode 37
Standard Timing Modes 38
Free Run 38
External Sync 40
External Sync with Continuous Cleans 42
Frame Transfer Operation 43
Interline Operation 45
Operating Modes 45
Timing Options in Overlapped Readout Mode 46

Chapter 6 Exposure and Readout 49

Exposure 49
Exposure with an Interline Array 50
Exposure with a Mechanical Shutter 50
Exposure with an Image Intensifier 51
Continuous Exposure (no shuttering) 51
Saturation 52
Dark Charge 52
Array Readout 53
Full Frame 53
Frame Transfer 55
Interline 56
Binning 59
Digitization 62
Dual A/D Converters 62

Chapter 7 MicroMAX DIF Camera (Double Image Feature)..... 65

Introduction....65
Timing Modes....66
Free Run....66
IEC (Internal Exposure Control)....68
EEC (External Exposure Control)....70
ESABI (Electronic Shutter Active Between Images)....71
Tips and Tricks....72
Lab Illumination....72
Background Subtraction....72
Flatfield Correction....73
Mask Bleed-Through Correction....73

Chapter 8 TTL Control..... 75

Introduction....75
TTL In....75
Buffered vs. Latched Inputs....76
TTL Out....76
TTL Diagnostics Screen....77
Hardware Interface....77
Example....78

Chapter 9 System Component Descriptions..... 79

MicroMAX Camera....79
ST-133 Controller....82
Cables....86
Interface Card....86
Application Software....87
User Manuals....87

Chapter 10 Troubleshooting..... 89

Introduction....89
Baseline Signal Suddenly Changes....89
Changing the ST-133's Line Voltage and Fuses....89
Controller Is Not Responding....90
Cooling Troubleshooting....91
Temperature Lock cannot be Achieved or Maintained.....91
Detector loses Temperature Lock....91
Gradual Deterioration of Cooling Capability....91
Detector Stops Working....92
Error occurs at Computer Powerup....92
Removing/Installing a Plug-In Module....95
Shutter Malfunctions....96

Appendix A Specifications 97

CCD Arrays....97
Spectral Range....97
Types....97

Temperature Control 97
Cooling 98
Mounting 98
Shutters 98
Inputs 99
Outputs 99
Programmable Interface 99
A/D Converter 99
Computer Requirements 99
Miscellaneous 100

Appendix B Outline Drawings 101

Appendix C Kinetics Mode 107

Introduction 107
Kinetic Timing Modes 108
Free Run 108
Single Trigger 109
Multiple Trigger 109

Appendix D Virtual Chip Mode 111

Introduction 111
Virtual Chip Setup 112
Introduction 112
Equipment: 112
Software: 112
Assumptions: 113
System Connection Diagram: 113
Procedure: 113
Experimental Timing 116
Virtual Chip dialog box 116
Tips 117

Appendix E Repumping the Vacuum 119

Introduction 119
Requirements 119
Vacuum Pumpdown Procedure 120

Warranty & Service 123

Limited Warranty: Roper Scientific Analytical Instrumentation 123
Limited One (1) Year Warranty 123
Sealed Chamber Integrity Warranty 123
Vacuum Integrity Warranty 123
Image Intensifier Detector Warranty 123
X-Ray Detector Warranty 124
Software Warranty 124
Owner's Manual and Troubleshooting 124
Your Responsibility 124
Contact Information 125

Index 127

Figures

Figure 1. MicroMAX Cameras and Controller 9
Figure 2. Standard System Diagram 16
Figure 3. 5 MHz System Diagram 16
Figure 4. Controller Power Input Module 18
Figure 5. Bottom Clamps 22
Figure 6. Bottom Clamp secured to Relay Lens 23
Figure 7. WinView Installation: Interface Card Driver Selection 24
Figure 8. Imaging Field of View 29
Figure 9. Monitor Display of CCD Image Center Area 30
Figure 10. Standard System Connection Diagram 31
Figure 11. 5 MHz System Diagram 32
Figure 12. F-mount Focus Adjustment 36
Figure 13. Chart of Full Speed (Synchronous) and Safe (Asynchronous) Operation 39
Figure 14. Free Run Timing Chart (part of the chart in Figure 13) 40
Figure 15. Free Run Timing Diagram 40
Figure 16. Chart Showing Two External Sync Timing Options 41
Figure 17. External Sync Timing Diagram 41
Figure 18. Continuous Cleans Flowchart 42
Figure 19. Continuous Cleans Timing Diagram 43
Figure 20. Frame Transfer where $t_{w1} + t_{exp} + t_c < t_R$ 44
Figure 21. Frame Transfer where $t_{w1} + t_{exp} + t_c > t_R$ 45
Figure 22. Frame Transfer where Pulse arrives after Readout 45
Figure 23. Overlapped Mode where $t_{w1} + t_{exp} + t_c < t_R$ 47
Figure 24. Overlapped Mode where $t_{w1} + t_{exp} + t_c > t_R$ 47
Figure 25. Overlapped Mode where Pulse arrives after Readout 48
Figure 26. Block Diagram of Light Path in System 49
Figure 27. CCD Exposure with Shutter Compensation 51
Figure 28. Full Frame at Full Resolution 53
Figure 29. Frame Transfer Readout 55
Figure 30. Overlapped Mode Exposure and Readout 57
Figure 31. Non-Overlapped Mode Exposure and Readout 58
Figure 32. 2 × 2 Binning for Full Frame CCD 60
Figure 33. 2 × 2 Binning for Interline CCD 61
Figure 34. Free Run Mode Timing Diagram 67
Figure 35. Setup using $\overline{\text{READY}}$ to Trigger an Event 67
Figure 36. Timing for Experiment Setup shown in Figure 35 67
Figure 37. Timing Diagram for Typical IEC Measurement 69
Figure 38. Setup for IEC Experiment with Two Lasers 69
Figure 39. Timing Diagram for IEC Experiment with Two Lasers 69
Figure 40. Another Hardware Setup for an IEC Measurement 70
Figure 41. EEC Timing Example with Exposure Time in Software Set to t_{exp} 71
Figure 42. ESABI Timing Example: Image Exposure time = t_{exp} set in software 72
Figure 43. TTL IN/OUT Connector 77
Figure 44. Controller Front Panel 82
Figure 45. ST-133 Rear Panel 83
Figure 46. $\overline{\text{SCAN}}$ and SHUTTER MONITOR Signals 86

Figure 47. Power Input Module 90
Figure 48. Fuse Holder 90
Figure 49. Module Installation 95
Figure 50. Controller Dimensions 101
Figure 51. Rectangular Camera Head: C-Mount 102
Figure 52. Rectangular Camera Head: F-Mount 103
Figure 53. 1 MHz and 100kHz/1MHz Round Head Camera: C-Mount Adapter and Shutter 104
Figure 54. 5 MHz Round Head Camera: C-Mount Adapter 105
Figure 55. 1 MHz Round Head Camera: F-Mount Adapter 106
Figure 56. Kinetics Readout 107
Figure 57. Hardware Setup dialog box 108
Figure 58. Experiment Setup dialog box 108
Figure 59. Free Run Timing Diagram 109
Figure 60. Single Trigger Timing Diagram 109
Figure 61. Multiple Trigger Timing Diagram 110
Figure 62. Virtual Chip Functional Diagram 111
Figure 63. System Diagram 113
Figure 64. Virtual Chip dialog box. 116
Figure 65. Vacuum Connector Required for Pumping 120
Figure 66. Removing the Back Panel 120
Figure 67. Attaching the Vacuum Connector 121
Figure 68. Opening the Camera to the Vacuum System 121

Tables

Table 1. Bottom Clamps for Different Microscopes 22
Table 2. Camera Timing Modes 37
Table 3. Approximate Readout Time for the Full-Frame CCD Array 54
Table 4. Approximate Readout Time for the Frame-Transfer CCD Array 55
Table 5. Approximate Readout Time for the Interline CCD Arrays 59
Table 6. Readout Rates for PI 1300 × 1030 Array at 1 MHz 59
Table 7. Well Capacity for some CCD Arrays 62
Table 8. Bit Values with Decimal Equivalents: 1 = High, 0 = Low 76
Table 9. TTL IN/OUT Connector Pinout 77
Table 10. ST-133 Shutter Drive Selection 85
Table 11. I/O Address & Interrupt Assignments before Installing Serial Card 93
Table 12. I/O Address & Interrupt Assignments after Installing Serial Card 93
Table 13. MicroMAX:512BFT: Virtual Chip Size, Exposure Time, and Frames per Second 112

Chapter 1
Introduction

Introduction

The Princeton Instruments® MicroMAX system is a high-speed, low-noise CCD camera system designed for demanding imaging applications and is an optimal system for use in fluorescence microscopy applications such as high resolution immunofluorescence, FISH or GFP imaging. The MicroMAX system incorporates a compact camera head, cooled CCD, advanced exposure-control timing, video output, and sophisticated readout capabilities.

Among the advantages of the MicroMAX concept are the range of CCD arrays available and the built-in video output mode. The system can be configured either with a variety of interline CCDs to provide true 12-bit images at a readout rate of up to 5 million pixels per second, or with a number of back-illuminated CCDs to provide true 16-bit images. The built-in video output mode simplifies setup and focusing on the microscope. The combination of the MicroMAX system with one of a variety of specialty software packages results in a powerful digital imaging system that can meet most experimental needs.

MicroMAX System Components

Overview

The MicroMAX imaging system consists of a camera (either a round head or a rectangular head depending on application), controller, digital interface card, a computer, cables, manuals, and application software. Together, these components allow you to acquire quantitative digital data under very low light imaging conditions. Each component is optimized for its specific function. In operation, data acquired by the camera is routed to the controller and from there to the computer for processing and display. A composite video output allows immediate viewing of the acquired images on a separate monitor. The application software (for example, Princeton Instruments WinView/32) allows the computer to control both the system configuration and data acquisition.

*Figure 1. Micro*MAX *Cameras and Controller*

Camera

Introduction: The function of the camera is to collect very low intensity light and convert the energy into a quantitative, electronic signal (photo-electrons) over a two dimensional space. To do this, light from the subject is focused onto a CCD array, which

accumulates photoelectrons for the exposure time. At the end of the exposure time, the image thus formed is read out. The accumulated charge on each cell of the array is transferred out of the CCD array, amplified, and sent to the controller as an analog signal, where it is digitized prior to transfer to the computer.

The camera is highly integrated, containing the shutter (if applicable) and thermoelectric cooler with optional forced-air supplemental cooling in a single, shielded housing. Surface mount electronic technology is used wherever possible, giving a compact package with uncompromising performance.

Depending on your application, the camera included in your MicroMAX system will be either a compact round camera head or a high performance, cooled, rectangular camera head. The round head features interline CCDs; its small size ensures that the camera can be mounted on virtually any microscope port, including those found on inverted microscopes. The rectangular head features back-illuminated CCDs with frame transfer readout.

At the heart of the camera is the CCD array centered on the optic axis. Available formats include the:

- EEV CCD57-10, 512×512, 13×13µm pixels for the MicroMAX:512BFT
- EEV CCD47-10, 1024×1024, 13×13µm pixels for the MicroMAX:1024B
- Sony ICX075, 782×582, 8.3× 8.3µm pixels for the MicroMAX:782Yand the MicroMAX:782YHS systems
- Sony ICX061,1300×1030, 6.7× 6.7µm pixels for the MicroMAX:1300Y, the MicroMAX:1300YHS, and MicroMAX:1300YHS-DIF systems

A special clocking mode to minimize background signal is supported. *See the Roper Scientific brochures and data sheets for detailed specifications.*

Cooling System: MicroMAX cameras have a multi-stage Peltier type cooler that is thermally coupled to the CCD surface. Heat is sequentially transferred through the Peltier stages and from there to the outer shell of the camera via a heat transfer block. This cooling system allows the camera to maintain CCD temperature of typically -15°C for round cameras head and -45°C for rectangular camera heads. Cameras equipped with a fan assembly can reach lower CCD temperatures for reduced thermal noise and extended exposure times.

Low Noise Readout: In order to achieve a low-noise readout of the CCD, several design features have been implemented. These include cooling the preamplifier on the CCD, isolating circuits to prevent electronic crosstalk and minimizing the path lengths of critical electronic circuits. The net result of these design features is the lowest available readout noise at the highest speed possible for these CCDs.

Controller

Data Conversion: The controller accepts the analog data and converts it to digital data using specially designed, low-noise electronics supporting scientific grade 12- or 16-bit Analog to Digital (A/D) converters.

The standard MicroMAX Controller enables both high-speed and high-precision readout capabilities. It can collect 16-bit images at a readout rate of up to 1 million pixels per second (1 MHz) in the high-speed mode or at 100 thousand pixels per second (100 kHz)

in the optional precision mode (16-bit). Switching between the two modes is under software control for total experiment automation.

The 5 MHz MicroMAX Controller provides 12-bit digitization at 5 MHz., resulting in a frame readout time of 0.33 seconds per full frame.

Modular Design: In addition to containing the power supplies, the controller contains the analog and digital electronics, scan control and exposure timing hardware, and system I/O connectors, all mounted on user-accessible plug-in modules. The design is highly modularized for flexibility and convenient servicing.

Flexible Readout: There is provision for extremely flexible readout of the CCD. Readout modes supported include full resolution, simultaneous multiple subimages, and nonuniform binning. Single or multiple software-defined regions of interest can also be tested without having to digitize all the pixels of the array

High Speed Data Transfer: Data is transferred directly to the host computer memory via a high-speed serial link. A proprietary Interface card places the data from the controller directly into the host computer RAM using Direct Memory Access (DMA). The DMA transfer process ensures that the data arrives at sufficiently high speed to prevent data loss from the controller. Since the data transfer rate is much higher than the output rate from the A/D, the latter becomes the data acquisition rate-limiting factor. Once the digital data is in RAM, the image acquisition program can transfer the image into its own working RAM for viewing and further processing.

Note: A frame buffer with standard composite video, either RS-170 (EIA) or CCIR, whichever was ordered, is also provided.

Applications

With its small size, fully integrated design, cooled CCD and temperature control, advanced exposure control timing, and sophisticated readout capabilities, the MicroMAX system is well suited to both general macro imaging and microscopy applications.

Computer Requirements

Note: Computers and operating systems all undergo frequent revision. The following information is only intended to give an approximate indication of the computer requirements. Please contact the factory to determine your specific needs.

Computer Type: Any Pentium® (or better) PC or Macintosh® computer having a free PCI slot.

Memory (RAM): Minimum of 32 Mbytes; possibly more depending on experiment design and size of CCD Array.

Operating System: Windows 95®, NT®, ME®, or 2000®

Interface: PCI High-Speed Serial I/O card. *Computers purchased from Roper Scientific as part of the MicroMAX system are shipped with the card installed.*

Computer Monitor: Super VGA monitor with 256 color graphics card and at least 512 kbytes of memory.

Mouse: Two-button Microsoft®-compatible serial mouse or Logitech three-button serial/bus mouse.

About this Manual

Manual Organization

This manual provides the user with all the information needed to install a MicroMAX camera and place it in operation. Topics covered include a detailed description of the camera, installation, cleaning, specifications and more.

Chapter 1, Introduction briefly describes the MicroMAX family of cameras; details the structure of this manual; and documents environmental, storage, and cleaning requirements.

Chapter 2, Installation Overview cross-references system setup actions with relevant manuals and/or manual pages. It also contains system layout diagrams.

Chapter 3, System Setup provides detailed directions for interconnecting the system components.

Chapter 4, Operation discusses number of topics, including temperature control, vacuum degradation, and sensitivity to damage from EMF spikes generated by Xenon or Hg arc lamps. Includes step-by-step directions for verifying system operation.

Chapter 5, Timing Modes discusses the basic Controller timing modes and related topics, including Synchronous vs. Asynchronous, Free Run, External Sync, Continuous, Frame Transfer, and Interline operation.

Chapter 6, Exposure and Readout discusses Exposure and Readout, together with many peripheral topics, including: shuttered and unshuttered exposure; saturation; dark charge; full frame, interline, and frame-transfer readout; and binning.

Chapter 7, MicroMAX DIF Camera (Double Image Feature) describes DIF (Dual Image Feature) camera and its operation.

Chapter 8, TTL Control provides information about how to use the TTL connector on the rear of the controller.

Chapter 9, System Component Descriptions provides descriptions of each system component.

Chapter 10, Troubleshooting provides courses of action to take if you should have problems with your system.

Appendix A, Specifications includes controller and camera specifications.

Appendix B, Outline Drawings includes outline drawings of the MicroMAX cameras and the ST-133 Controller.

Appendix C, Kinetics Mode describes how to set up and acquire data with the Kinetics option, which allows frame transfer CCDs to take time-resolved images/spectra.

Appendix D, Virtual Chip Mode describes how to set up and use the Virtual Chip option, a special fast-acquisition technique.

Appendix E, Repumping the Vacuum explains how to restore the 1 MHz or 100kHz/1MHz round head camera's vacuum if that vacuum has deteriorated over time.

Safety Related Symbols Used in This Manual

Caution! The use of this symbol on equipment indicates that one or more nearby items should not be operated without first consulting the manual. The same symbol appears in the manual adjacent to the text that discusses the hardware item(s) in question.

Caution! Risk of electric shock! The use of this symbol on equipment indicates that one or more nearby items pose an electric shock hazard and should be regarded as potentially dangerous. This same symbol appears in the manual adjacent to the text that discusses the hardware item(s) in question.

Environmental Conditions

- Storage temperature: < 55°C
- Operating environment: 0°C to 30°C
- Relative humidity: ≤50%, non-condensing.

Grounding and Safety

The apparatus described in this manual is of the Class I category as defined in IEC Publication 348 (Safety Requirements for Electronic Measuring Apparatus). It is designed for indoor operation only. Before turning on the controller, the ground prong of the power cord plug must be properly connected to the ground connector of the wall outlet. The wall outlet must have a third prong, or must be properly connected to an adapter that complies with these safety requirements.

WARNING

If the equipment is damaged, the protective grounding could be disconnected. Do ***not*** use damaged equipment until its safety has been verified by authorized personnel. Disconnecting the protective earth terminal, inside or outside the apparatus, or any tampering with its operation is also prohibited.

Inspect the supplied power cord. If it is not compatible with the power socket, replace the cord with one that has suitable connectors on both ends.

WARNING

Replacement power cords or power plugs must have the same polarity as that of the original ones to avoid hazard due to electrical shock.

Precautions

To prevent permanently damaging the system, please observe the following precautions:

- Always switch off and unplug the ST-133 Controller before changing your system configuration in any way.
- Never remove the camera's front window, as it is necessary to maintain vacuum (or to maintain a dry nitrogen environment).
- The CCD array is very sensitive to static electricity. Touching the CCD can destroy it. Operations requiring contact with the device can only be performed at the factory.
- Never operate the camera cooled without proper evacuation or backfill. This could damage the CCD!
- Never connect or disconnect any cable while the MicroMAX system is powered on. Reconnecting a charged cable may damage the CCD.
- Never prevent the free flow of air through the equipment by blocking the air vents.

Repairs

Repairs must be done by Roper Scientific. If your system hardware needs repair, contact Roper Scientific Customer Service. Please save the original packing material so you can safely ship the system to another location or return it for repairs.

Cleaning

WARNING! Turn off all power to the equipment and secure all covers before cleaning the units. Otherwise, damage to the equipment or personal injury could occur.

Camera and Controller

Although there is no periodic maintenance that *must* be performed on the camera or the ST-133 Controller, you may clean these components from time to time by wiping them down with a clean damp cloth. This operation should only be done on the external surfaces and with all covers secured. In dampening the cloth, use clean water only. No soap, solvents or abrasives should be used. Not only are they not required, but they could damage the finish of the surfaces on which they are used.

Optical Surfaces

Optical surfaces may need to be cleaned due to the accumulation of atmospheric dust. We advise that the *drag-wipe* technique be used. This involves dragging a clean cellulose lens tissue dampened with clean anhydrous methanol over the optical surface to be cleaned. Do not allow any other material to touch the optical surfaces.

Roper Scientific Customer Service

Refer to the contact information located on page 125 of this manual.

Chapter 2
Installation Overview

The list and diagrams below briefly describe the sequence of actions required to hookup your system and prepare to gather data. Refer to the indicated references for more detailed information. This list assumes that the application software is Princeton Instruments WinView/32.

Action	Reference
1. If the system components have not already been unpacked, unpack them and inspect their carton(s) and the system components for in-transit damage. Store the packing materials.	Chapter 3 System Setup, page 16
2. Verify that all system components have been received.	Chapter 3 System Setup, page 17
3. If the components show no signs of damage, verify that the appropriate voltage settings have been selected for the Controller.	Chapter 3 System Setup, page 18
4. If the WinView/32 software is not already installed in the host computer, install it. This will install the appropriate drivers for the interface card.	WinView/32 manual
5. If the appropriate interface card is not already installed in the host computer, install it.	Chapter 3 System Setup, page 24
6. If using a microscope, mount the Camera.	Chapter 3 System Setup, page 20
7. With the Controller power turned OFF, make the camera-to-controller connections to the back of the Controller. If making connections for a 5 MHz system, hook up the 15-pin Power cable before the 40-pin Signal cable (***the right angle connectors attach to the camera)***. Secure the latch(es) to lock the cable connection(s).	Chapter 3 System Setup, page 25
8. With the Controller power turned OFF, make the camera-to-controller connections to the back of the Camera. If making connections for a 5 MHz system, hook up the 15-pin Power cable before the 40-pin Signal cable (***the right angle connectors attach to the camera)***. Secure the latch(es) to lock the cable connection(s).	Chapter 3 System Setup, page 25
9. With the Controller and computer power turned OFF, connect the TAXI® cable to the Controller and the interface card in the host computer. Then tighten down the locking hardware.	Chapter 3 System Setup, page 25
10. With the Controller power turned OFF, connect the Controller power cable to the rear of the controller and to the power source.	

Action	Reference
11. If using a microscope Xenon or an Hg arc lamp, turn it on before turning on the controller and host computer.	Chapter 4 Operation, page 27
12. Turn the Controller ON.	
13. Turn on the computer and begin running WinView/32.	WinView/32 manual
14. Enter the hardware setup information or load the defaults from the controller.	Chapter 4 Operation, page 33
15. Set the target array temperature.	Chapter 4 Operation, page 27
16. When the system reaches temperature lock, begin acquiring data in focus mode.	Chapter 4 Operation, page 29
17. Adjust the focus for the image.	Chapter 4 Operation, page 34

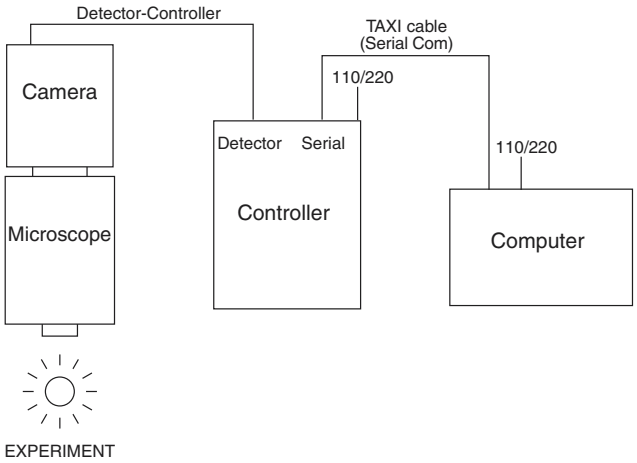


Figure 2. Standard System Diagram

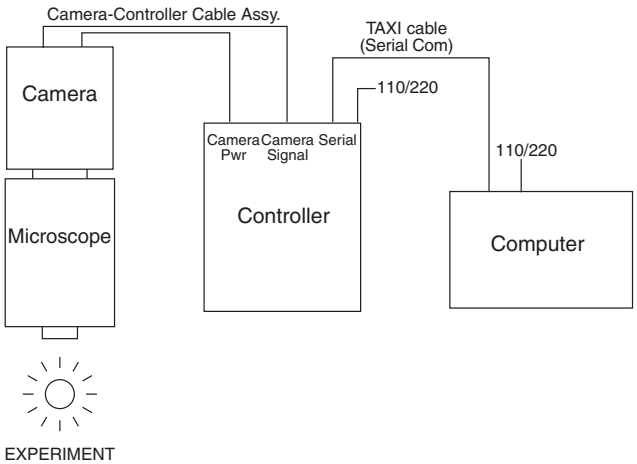


Figure 3. 5 MHz System Diagram

Chapter 3
System Setup

Unpacking the System

During the unpacking, check the system components for possible signs of shipping damage. If there are any, notify Roper Scientific and file a claim with the carrier. If damage is not apparent but camera or controller specifications cannot be achieved, internal damage may have occurred in shipment. Please save the original packing materials so you can safely ship the camera system to another location or return it to Roper Scientific for repairs if necessary.

Checking the Equipment and Parts Inventory

Confirm that you have all of the equipment and parts required to set up the system. A complete MicroMAX system consists of a camera, a controller, a computer and other components as follows.

- **Camera to Controller cable:**

  Standard MicroMAX: DB25 to DB25, 10 ft. Two versions of this cable are available, one having an external shield and the other not. The shielded version offers superior noise performance and is required by regulation in some countries.

  5MHz MicroMAX: DB15 to DB15 and high-density DB40 to DB40.

- **Controller to Computer cable:** DB9 to DB9 cable. Standard length is 25 ft (PI #6050-0148). Lengths up to 165 ft (50 m) are available. Optional fiber-optic transducers can be used to extend this distance to as much as 1000 m.
- **High Speed PCI Interface Board (PC or Macintosh**): This board must be installed in the computer. Computers purchased from Roper Scientific will be shipped with the board already installed.
- **Vacuum Pumpdown connector (2550-0181):** This item is required if it becomes necessary to refresh the vacuum for round camera heads. *Contact the factory Technical Support Dept. for information on refreshing the vacuum. See page 123 for contact information.*
- **WinView/32 CD-ROM**
- **User Manual**

Power Requirements

The MicroMAX system can operate from any one of four different nominal line voltages, 100, 120, 220, or 240 V AC. The power consumption is nominally 200 watts and the line frequency can range from 47 to 63 Hz.

The MicroMAX camera receives its power from the controller, which in turn plugs into a source of AC power. The plug on the line cord supplied with the system should be compatible with the line-voltage outlets in common use in the region to which the system is shipped. If the line cord plug is incompatible, a compatible plug should be installed, taking care to maintain the proper polarity to protect the equipment and assure user safety.

Verifying Controller Voltage Setting

The Power Input Module on the rear of the Controller contains the voltage selector drum, fuses and the powercord connector. The appropriate voltage setting is set at the factory and can be seen on the power input module.

Each setting actually defines a range and the setting that is closest to the actual line voltage should have been selected. The fuse and power requirements are printed on the panel above the power input module. The correct fuses for the country where the ST-133 is to be shipped are installed at the factory.

To Check the Controller's Voltage Setting:

1. Look at the lower righthand corner on the rear of the Controller. The current voltage setting (100, 120, 220, or 240 VAC) is displayed on the Power Input Module.
2. If the setting is correct, continue with the installation. If it is not correct, follow the instructions on page 89 for changing the ST-133 Controller's voltage setting and fuses.

Figure 4. Controller Power Input Module

Mounting the Camera

General

The MicroMAX camera can be mounted either horizontally or vertically (nose up or nose down). The camera can rest on any secure surface. For mounting flexibility, the round head camera is equipped with four standard ¼″ x 20 UNC threaded 3/8″ deep holes spaced at 90° intervals around the body; in some situations it may prove convenient to secure the camera with a suitable mounting bracket. An optional tripod mount is available for the rectangular head camera.

WARNING

In the case of cameras equipped with F-mount, do not mount the camera in the *nose-up* operation where the lens mount would be required to hold the camera's weight. The F-mount is not designed to sustain the weight of the camera in this orientation and the camera could pull free. *Contact the factory for special mounting options that enable operation in this orientation.*

Should the camera be mounted in the nose-up position beneath a table, take care to protect the mounting components from lateral stresses, such as might occur should someone accidentally bump the camera with a knee while working at the table. Two possible approaches to this problem would be to install a securely mounted bracket to the camera or to install a barrier between the camera and operator so as to prevent any accidental contact.

There are no special constraints on nose-down operation. Again, however, good operating practice might make it advisable to use a securing bracket to prevent accidental contact from unduly stressing the mounting components.

If the camera is going to be mounted to a microscope, the lens mounting instructions that follow will not apply. Where this is the case, users are advised to skip the following discussion and instead review *Mounting to a Microscope,* beginning on page 20.

Mounting the Lens

The MicroMAX camera is supplied with the lens mount specified when the system was ordered, normally either a screw-type C-mount lens or a bayonet type F-mount lens, allowing a lens of the corresponding type to be mounted quickly and easily.

C-mount lenses simply screw clockwise into the threaded lens mount at the front of the camera. In mounting a C-mount lens, tighten it securely by hand *(no tools)*.

Note: C-mount cameras are shipped with a dust cover lens installed (identifiable by its red rim). Although this lens is capable of providing images, its throughput is low and the image quality is not as good as can be obtained with a high quality camera lens. You should replace the dust cover lens with your own high quality laboratory lens before making measurements.

To mount an F-mount lens on the camera, locate the large indicator dot on the side of the lens. There is a corresponding dot on the front side of the camera lens mount. Line up the dots and slide the lens into the mount. Then turn the lens counterclockwise until a click is heard. The click means that the lens is now locked in place.

Removing either type lens is equally simple. In the case of a C-mount lens, simply rotate the lens counterclockwise until it is free of the mount. In the case of an F-mount lens,

press the locking lever on the mount while rotating the lens clockwise until it comes free and can be pulled straight out.

Both types of lenses typically have provision for focusing and aperture adjustment, with the details varying according the make and model of the lens. In addition, in the case of the F-mount, there is provision for adjusting the focus of the lens mount itself, if necessary, to bring the focus within range of the lens focus. See the discussion on page 35 for more detailed information.

Mounting procedures are more complex when mounting to a microscope and vary according to the make and model of the microscope as discussed in *Mounting to a Microscope,* which follows.

Mounting to a Microscope

This section discusses the setup and optimization of your digital imaging system as applied to microscopy. Since scientific grade cooled CCD imaging systems are usually employed for low light level microscopy, the major goal is to maximize the light throughput to the camera. In order to do this, the highest Numerical Aperture (NA) objectives of the desired magnification should be used. In addition, you should carefully consider the transmission efficiency of the objective for the excitation and emission wavelengths of the fluorescent probe employed. Another way to maximize the transmission of light is to choose the camera port that uses the fewest optical surfaces in the pathway, since each surface results in a small loss in light throughput. Often the trinocular mount on the upright microscope and the bottom port on the inverted microscope provide the highest light throughput. Check with the manufacturer of your microscope to determine the optimal path for your experiment type.

A rule of thumb employed in live cell fluorescence microscopy is “if you can see the fluorescence by eye, then the illumination intensity is too high”. While this may not be universally applicable, it is a reasonable goal to aim for. In doing this, the properties of the CCD in your camera should also be considered in the design of your experiments. For instance, if you have flexibility in choosing fluorescent probes, then you should take advantage of the higher Quantum Efficiency (QE) of the CCD at longer wavelengths (contact factory for current CCD specifications). Another feature to exploit is the high resolution offered by cameras with exceptionally small pixel sizes (6.7 µm for MicroMAX:1300Y, 1300YHS, and 1300YHS-DIF or 8.3µm for MicroMAX:782Y and 782YHS). Given that sufficient detail is preserved, you can use 2x2 binning (or higher) to increase the light collected at each “super-pixel” by a factor of 4 (or higher). This will allow the user to reduce exposure times, increasing temporal resolution and reducing photodamage to the living specimen.

Another method to minimize photodamage to biological preparations is to synchronize a shutter on the excitation pathway to the exposure period of the camera. This will limit exposure of the sample to the potentially damaging effects of the excitation light. Timing and synchronization are explained in Chapter 5.

The camera is connected to the microscope via a standard type mount coupled to a microscope specific adapter piece. There are two basic camera mounting designs, the C-mount and the F-mount. The C-mount employs a standard size thread to connect to the camera to the adapter while the F-mount uses a tongue and groove type mechanism to make the connection.

C-Mount

For a camera equipped with a C-mount thread, use the standard C-mount adapter supplied by the microscope manufacturer to attach the camera to the microscope. The adapter can be screwed into the camera and then the assembly can be secured to the microscope using the standard setscrews on the microscope. The camera can be mounted on the trinocular output port, the side port, or the bottom port of the inverted microscope. When mounting the larger cameras perpendicular to the microscope on the side port, it is ADVISED that you provide some additional support for your camera to reduce the possibility of vibrations or excessive stress on the C-mount nose. For the bottom port of the inverted microscope, the C-mount is designed to support the full weight of the camera, however, IT IS ADVISED that you provide some additional support for the larger cameras since the camera is in a position where it could be deflected by the operator's knee or foot. This kind of lateral force could damage the alignment of the nose and result in sub-optimal imaging conditions.

Most output ports of the microscope do not require additional optical elements to collect an image, however please check with your microscope manual to determine if the chosen output port requires a relay lens. In addition, all optical surfaces should be free from dust and fingerprints, since these will appear as blurry regions or spots and hence degrade the image quality.

F-Mount

For a camera with the F-mount type design, you will need two elements to mount the camera on your microscope. The first element is a Diagnostic Instruments Relay Lens. This lens is usually a 1X relay lens that performs no magnification. Alternatively, you may use a 0.6X relay lens to partially demagnify the image and to increase the field of view. There is also a 2X relay lens available for additional magnification. The second element is a microscope specific Diagnostic Instruments Bottom Clamp. Table 1 shows which bottom clamps are routinely used with each of the microscope types. They are illustrated in Figure 5. If you feel that you have received the wrong type of clamp, of if you need a clamp for a microscope other than those listed, please contact the factory.

To assemble the pieces, first pick up the camera and look for the black dot on the front surface. Match this dot with the red dot on the side of the relay lens. Then engage the two surfaces and rotate them until the F-mount is secured as evidenced by a soft clicking sound. Next place the long tube of the relay lens into the bottom clamp for your microscope, securing it to the relay lens with the three setscrews at the top of the clamp as shown in Figure 6. This whole assembly can now be placed on the microscope, using the appropriate setscrews on the microscope to secure the bottom clamp to the output port of the microscope.

Microscope Type	Diagnostic Instruments Bottom Clamp Type
Leica DMR	L-clamp
Leitz All types	NLW-clamp
Nikon Optiphot, Diaphot, Eclipse	O-clamp
Olympus BH-2, B-MAX, IMT-2	V-clamp
Zeiss Axioscope, Axioplan, Axioplan 2, Axiophot	Z-clamp
Zeiss Axiovert	ZN-clamp

Table 1. Bottom Clamps for Different Microscopes

The F-mount is appropriate for any trinocular output port or any side port. When mounting the camera perpendicular to the microscope on the side port, it is ADVISED that you provide some additional support for your camera to reduce the possibility of vibrations or excessive stress on the F-mount nose. Roper Scientific DOES NOT advise using an F-mount to secure the camera to a bottom port of an inverted microscope due to possible failure of the locking mechanism of the F-mount. *Contact the factory for information about a special adapter for operating in this configuration.*

Focusing information for a camera and a camera lens mount is included in the *First Light* section of Chapter 4 (page 35). Although it is unlikely that you would ever need to use the lens mount adjustment in operation with a microscope (the relay-lens focus adjustment would normally suffice), it could be used if necessary. The procedure for using the adjustment is provided in Chapter 4 and illustrated in Figure 12.

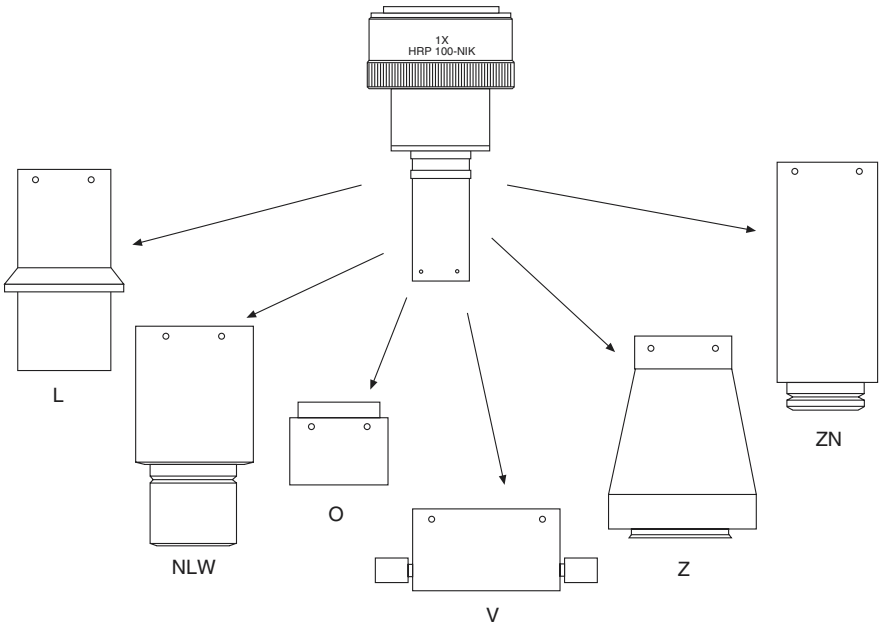


Figure 5. Bottom Clamps

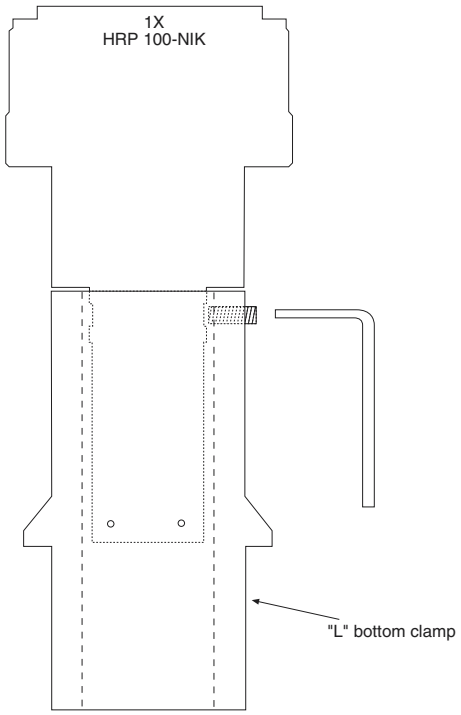


Figure 6. Bottom Clamp secured to Relay Lens

CAUTION

Microscope optics have very high transmission efficiencies in the infrared region of the spectrum. Since typical microscope light sources are very good emitters in the infrared, some microscopes are equipped with IR blockers or heat filters to prevent heating of optical elements or the sample. For those microscopes that do not have the better IR blockers, the throughput of infrared light to the CCD can be fairly high. In addition, while the eye is unable to see the light, CCD cameras are particularly efficient in detecting infrared wavelengths. As a result, the contaminating infrared light will cause a degradation of the image quality due to a high background signal that will be invisible to the eye. Therefore, it is recommended that you add an IR blocker in the light path if you encounter this problem with the microscope.

Installing the Application Software

Drivers

Installation is performed via the WinView/32 installation process, which should be done before the interface card is installed in the host computer. On the **Select Components** dialog box (see Figure 7), click on the button appropriate for the interface card. For a PCI card, select the **AUTO PCI** component to install the required PCI card driver and the most commonly installed program files. If you do not want to install the PCI driver or would like to choose among the available program files, select the **Custom** component. If the interface card was installed at the factory, the appropriate driver was installed at that time.

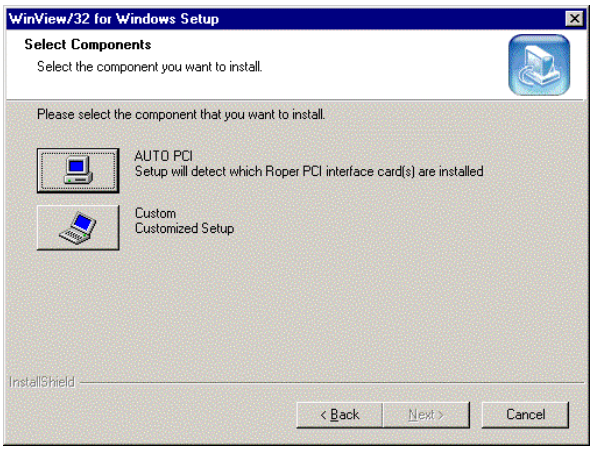


Figure 7. WinView Installation: Interface Card Driver Selection

Note: WinView/32 (versions 2.5.0 and higher) do not support the ISA interface.

Installing the Interface Card

If the computer is purchased from Roper Scientific, it will be shipped with the Serial Buffer card already installed. PCI Interface boards are standard. In the past, ISA had been supported but with WinView/32 versions 2.5.0 and higher, this support is no longer available.

CAUTION

If using WinView/32 software, either **High Speed PCI** or **PCI(Timer)** can be the selected Interface type. This selection is accessed on the **Hardware Setup|Interface** tab page. **High Speed PCI** allows data transfer to be interrupt-driven and gives the highest performance in some situations. **PCI(Timer)** allows data transfer to be controlled by a polling timer. This selection is recommended when there are multiple devices sharing the same interrupt.

To Install a PCI Serial Buffer Card:

1. Review the documentation for your computer and PCI card before continuing with this installation.
2. To avoid risk of dangerous electrical shock and damage to the computer, verify that the computer power is OFF.
3. Remove the computer cover and verify that there is an available PCI slot.
4. Install the PCI card in the slot.
5. Make sure that the card is firmly seated and secure it.
6. Replace and secure the computer cover and turn on the computer only. If an error occurs at bootup, either the PCI card was not installed properly or there is an address or interrupt conflict. Go to Chapter 10,"Troubleshooting", page 92 for instructions.

To Install an ISA Serial Card:

Support for ISA Serial boards has been discontinued as of the release of WinView/32 version 2.5.0. Earlier versions of the software still support this board. If you are using an earlier version of the WinView software and want to install an ISA card, contact the factory for instructions.

Note: An ISA serial interface card operated in an ISA slot can support data transfer rates as high as 1 MHz (WinView software ver. 1.4.3 - 2.4.8).

Connecting the TAXI (Controller-Computer) Cable

Turn the Controller power OFF (OFF = 0, ON = |) and the Computer power OFF before connecting or disconnecting the Controller-Computer (TAXI) cable.

To Connect the TAXI Cable:

1. Verify that the Controller power is OFF.
2. Verify that the Computer power is OFF.
3. Connect one end of the TAXI cable to the 9-pin port on the Interface card.
4. Tighten down the screws to lock the connector in place.
5. Connect the other end of the cable to the "Serial Com" port on the rear of the Controller.
6. Tighten down the screws to lock the connector in place.

Connecting the Detector-Controller Cable or the Camera Power/Camera Signal Cables

CAUTION Turn the Controller power OFF (OFF = 0, ON = |) before connecting or disconnecting the Detector-Controller cable or the Camera Power/Camera Signal Cables.

To Connect the Detector-Controller Cable:

1. Verify that the Controller power is OFF.
2. Connect male end of the Detector-Controller cable to the “Detector” port on the back of the Controller.
3. Move the slide latch over to lock the connector in place.
4. Connect the female end of the cable to the Camera.
5. Move the slide latch over to lock the connector in place.

To Connect the Camera Power/Camera Signal Cables (5 MHz only):

1. Verify that the Controller power is OFF.

   Note: When installing the cable assembly at the Controller, the 15-pin Camera Power connector must be installed before the 40-pin Camera Signal connector. If removing the cable assembly, this sequence is reversed.

2. Connect male end of the Camera Power cable to the “Camera Power” port on the back of the Controller and move the slide latch over to lock the connector in place.
3. Connect male end of the Camera Signal cable to the “Camera Signal” port on the back of the Controller and make sure that the spring-loaded latch is locking the connector in place.
4. Connect the female end of the Camera Power cable to the Camera and move the slide latch over to lock the connector in place.
5. Connect the female end of the Camera Signal cable to the Camera and make sure that the spring-loaded latch is locking the connector in place.

Chapter 4
Operation

Introduction

This chapter begins with sections regarding a number of operating considerations such as EMF, vacuum, cooling, baseline signal, and imaging field of view. The final section provides a step-by-step procedure for placing the system in operation the first time. At this point a lens should be mounted on the camera (or, if necessary, the camera mounted on a microscope) and you should be ready to operate the system and proceed to viewing your first MicroMAX images.

EMF and Xenon or Hg Arc Lamps

WARNING

Before You Start, if your imaging system includes a microscope Xenon or Hg arc lamp, it is **CRITICAL** to turn off all electronics adjacent to the arc lamp, especially your digital camera system and your computer hardware (monitors included) before turning on the lamp power.

Powering up a microscope Xenon or Hg arc lamp causes a large EMF spike to be produced that can cause damage to electronics that are running in the vicinity of the lamp. We advise that you place a clear warning sign on the power button of your arc lamp reminding all workers to follow this procedure. While Roper Scientific has taken great care to isolate its sensitive circuitry from EMF sources, we cannot guarantee that this protection will be sufficient for all EMF bursts. *Therefore, in order to fully guarantee the performance of your system, you must follow this startup sequence.*

Vacuum

The camera's CCD chamber is pumped to a vacuum level of ~10 mTorr or better at the factory. This level of vacuum is necessary to be assured of achieving temperature lock and to prevent condensation from damaging the CCD array. Because outgassing continues for some time in new units, the vacuum could degrade, which would make it increasingly difficult to achieve temperature lock. Temperature lock can be restored by repumping the vacuum. *Contact the factory Technical Support Dept. for information on refreshing the vacuum. See page 123 for contact information.*

Cooling

Most MicroMAX cameras must be cooled during operation. A Peltier-effect thermoelectric cooler, driven by closed-loop proportional-control circuitry, cools the CCD. A thermal sensing diode attached to the cooling block of the camera monitors its temperature. Heat generated at the exhaust plate of the cooler is conducted to the

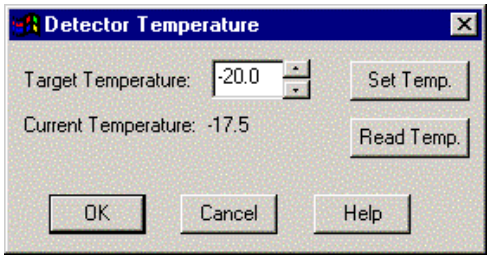
enclosure of the camera. Fins on the round head camera shell radiate the heat outward to the surrounding atmosphere. The fan inside the rectangular head camera draws air through the vents in the camera shell, blows it through the internal fins, and exhausts it back into the atmosphere through the vents.

MicroMAX CCDs typically have the following temperature ranges:

- Better than -15°C with passive cooling and under vacuum
- Better than -30°C with the optional forced air accessory and under vacuum

Setting the Temperature

The temperature of the CCD array is set through software. With WinView/32, you enter and set the target temperature after selecting **Detector Temperature** from the **Setup** menu.



Temperature Stabilization

After the system begins cooling, it takes from 10-20 minutes for the CCD to reach its preset temperature. Because the control loop is designed to achieve temperature lock as quickly as possible, overshoot may occur. If this happens, temperature lock will be briefly indicated and then discontinue during the overshoot. However, the lock indication will be quickly restored as stable control is re-established. This is normal behavior and should not be a cause for concern. Once temperature lock is established, the temperature is thermostated to within ±0.050°C. The controller is equipped with an LED that indicates temperature lock: this indicator may simply light or it may change color from orange to green to indicate lock.

Note: The time to reach temperature lock is affected by CCD array size and the ambient temperature. Typically, the larger the array or the warmer the ambient temperature, the longer the time to reach lock. Temperature regulation does not reach its ultimate stability for at least 30 minutes after lock is established.

Baseline Signal

With the camera completely blocked, the CCD will collect a dark charge pattern, dependent on the exposure time and camera temperature. The longer the exposure time and the warmer the camera, the larger and less uniform this background will appear.

Note: Do not be concerned about either the DC level of this background or its shape unless it is very high (i.e., 400 counts). What you see is not noise. It is a fully subtractable readout pattern. Each CCD has its own dark charge pattern, unique to that particular device. Every device has been thoroughly tested to ensure its compliance with Roper Scientific's demanding specifications.

CAUTION

If you observe a sudden change in the baseline signal you may have excessive humidity in the vacuum enclosure of the camera. Turn off the controller and have the camera repumped before resuming normal operation. *Contact the factory Technical Support Dept. for information on how to refresh the vacuum. See page 125 for contact information.*

Imaging Field of View

When used for two-dimensional imaging applications, the MicroMAX camera closely imitates a standard 35 mm camera. Since the CCD is not the same size as the film plane of a 35 mm camera, the field of view at a given distance is somewhat different. The imaging field of view is indicated in Figure 8.

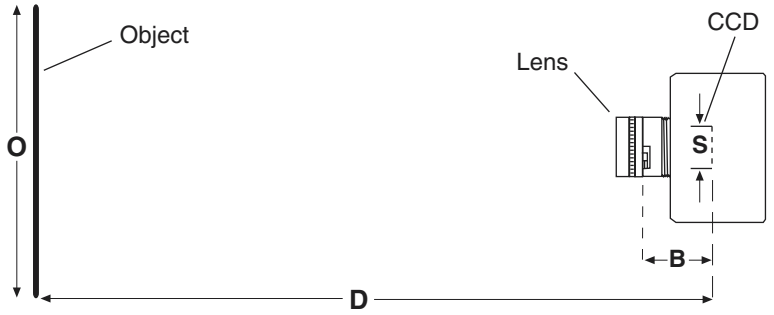


Figure 8. Imaging Field of View

D = distance between the object and the CCD

B = 46.5 mm for F-mount; 17.5 mm for C-mount

F = focal length of lens

S = CCD horizontal or vertical dimension

O = horizontal or vertical field of view covered at a distance D

M = magnification

The field of view is:

$$O = S/M, \text{ where } M = \frac{FD}{(D - B)^2}$$

RS-170 or CCIR Video

One of the limitations of scientific non-video rate cameras has been their difficulty in focusing and locating fields of view. The MicroMAX solves this problem by its combination of high speed operation with the implementation of true video output. The high-speed image update on the video monitor (via the **VIDEO** BNC connector on the rear of the Controller) makes focusing and field location as simple as with a video camera. This video output also makes possible archiving an experiment on a VCR, producing hardcopy data on a video printer, or even implementing autofocusing stages.

Note: If more than one device is connected to the video output, the ***last*** device is the one that should to be terminated in 75Ω. For example, to connect the video output to a VCR as well as to a monitor, the cable from the controller video output should be connected to the video input connector of the VCR, and another 75 Ω cable should extend from the video output connector of the VCR to the 75Ω input of the monitor. Do *not* use a BNC TEE to connect the controller video output to multiple devices.

The video output is selected by the Application software. In the case of WinView/32, this is done by selecting **Video** from the Acquisition menu. There is also provision in WinView/32 for intensity-scaling the video output, that is, selecting the specific gray levels to be displayed on the 8-bit video output.

In addition to intensity-scaling, you also need to be concerned about how the array pixels map to the video display. The 756×486 resolution of a typical video monitor corresponds well with the array size of a MicroMAX:782Y, MicroMAX:782YHS or MicroMAX:512BFT

In the case of a MicroMAX:1300YHS or a MicroMAX:1300YHS-DIF, the number of array pixels far exceeds the number of monitor pixels and mapping must be considered more carefully. WinView/32 software's **Video Focus** mode (accessed from the Acquisition Menu) provides a Pan function that allows any one of nine different subsets of the array image to be selected for viewing on the video monitor with only a single-frame delay. An associated zoom function provides 1x, 2x, or 4x viewing. At 1x, the entire array image is displayed, but at reduced resolution (pixels are discarded and fine detail could be lost). At 2x, the mapping is 1:1 and the image portion selected by the Pan function is provided. The regions overlap, allowing the entire array image to be examined with no loss of resolution. At 4x, array pixels are enlarged so that a smaller part of the array image is displayed as selected by the Pan function.

Once proper focus has been achieved, the user can transfer to normal data-acquisition operation. The video output remains operative, but with a more limited and fixed view because of the resolution limitation of RS-170 video. Although this view is sufficient to cover the image from a small CCD array in its entirety, it will not cover all the pixels from a large array. Instead, a subset from the center of the image will be shown. For example, in the case of the MicroMAX:1300YHS, the monitor would display the 756×486 area from the center of the CCD image as shown in Figure 9.

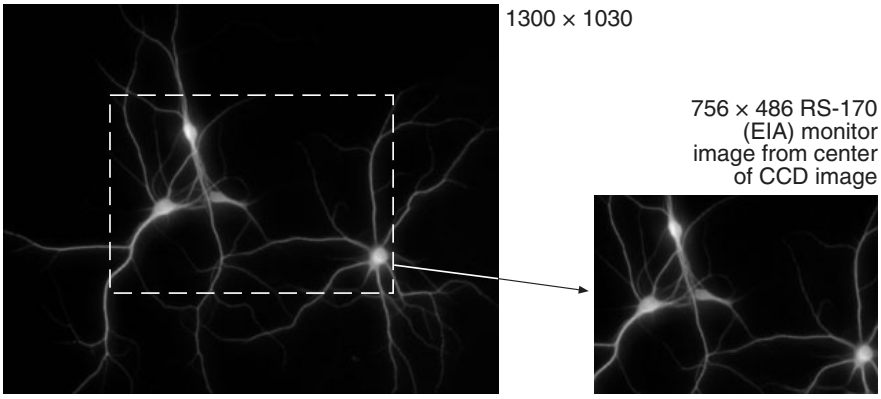


Figure 9. Monitor Display of CCD Image Center Area

Note: With a 16-bit A/D converter (***not*** a standard option), the composite video output is disabled during data acquisition.

In post-acquisition processing the WinView/32 ROI (Region of Interest) capability allows any portion of an acquired image to be displayed on the computer monitor.

Again, note that the described video output behavior applies specifically for the WinView/32 software only. Other application software may provide different video output capabilities.

First Light

The following paragraphs provide step-by-step instructions for placing your MicroMAX system in operation the first time. The intent of this simple procedure is to help you gain basic familiarity with the operation of your system and to show that it is functioning properly. Once basic familiarity has been established, then operation with other operating configurations, ones with more complex timing modes, can be performed. An underlying assumption for the procedure is that the camera is to be operated with a microscope on which it has been properly installed (see *Mounting to a Microscope,* page 20*,* for mounting instructions) and that a video monitor is available. Although it is possible to dispense with the monitor and simply view the images on the computer monitor's screen, operations such as focusing may be easier with a video monitor because the displayed data is updated much more quickly and will be as close to current as possible.

Once the MicroMAX camera has been installed and its optics adjusted, operation of the camera is basically straightforward. In most applications you simply establish optimum performance using the **Focus** mode (WinView/32), set the target camera temperature, wait until the temperature has stabilized, and then do actual data acquisition in the **Acquire** mode. Additional considerations regarding experiment setup and equipment configuration are addressed in the software manual.

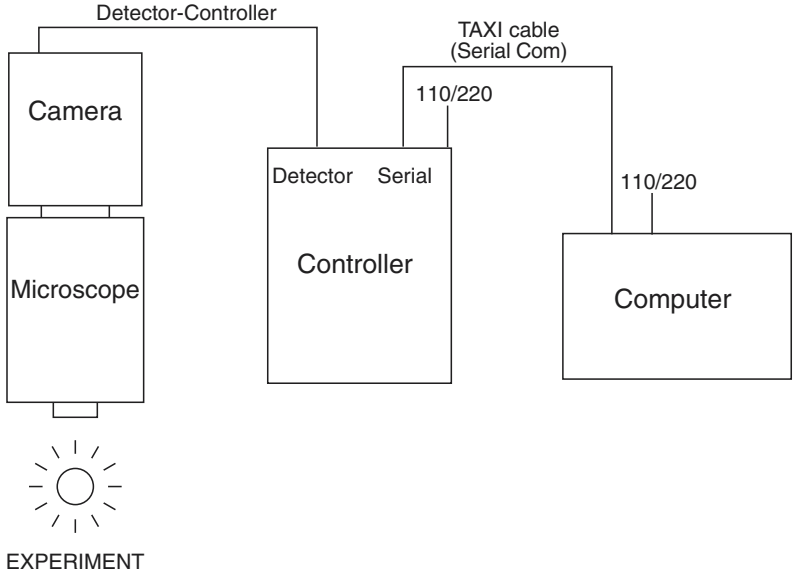


Figure 10. Standard System Connection Diagram

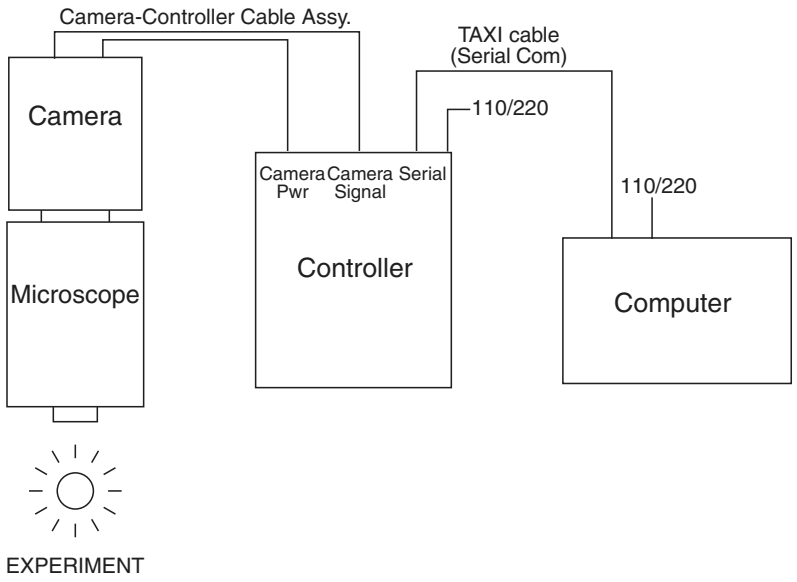


Figure 11. 5 MHz System Diagram

Cabling

If the system cables haven't as yet been installed, connect them as follows (system power OFF): If the system cables haven't as yet been installed, connect them as follows (system power off). *See Figure 10 or Figure 11.*

- Connect the camera-to-controller cable(s):

  Standard System: Connect the 25-pin cable from the **DETECTOR** connector on the Analog/Control module panel to the mating connector at the back of the camera. Secure the cable at both ends with the slide-lock latch.

  5 MHz System: ***Connection sequence is important.*** Connect the 15-pin Power connector to the connector on the Analog/Control panel and to the mating connector on the back of the camera. Then, connect the 40-pin Signal connector to the connector on the Analog/Control panel and the mating connector on the back of the camera. Secure the 15-pin connectors at both ends with the slide-lock latch and the 40-pin connectors with the spring-loaded latch. When removing the cable assembly, this sequence is reversed.

- Connect one end of the 9-pin serial cable to the **SERIAL COM** connector on the Interface Control module panel. Connect the other end to the computer interface as described in Chapter 3. Be sure to secure both ends of the cable with the cable-connector screws.

- Connect a 75 Ω BNC cable from the **VIDEO** connector on the back of the camera to the video monitor's 75 Ω input. This cable must be terminated in 75 Ω. Many monitors have a switch for selecting the 75 Ω termination.

- Connect the line cord from the Power Input assembly on the back of the controller to a suitable source of AC power.

Getting Started

1. If you haven't already done so, install a lens on the camera. The initial lens settings aren't important but it may prove convenient to set the focus to approximately the anticipated distance and to begin with a small aperture setting. In the case of operation with a microscope, review *Mounting to a Microscope*, beginning on page 20, and mount the camera on the microscope.
2. Turn on the system power. *The Power On/Off switch is located on the front of the controller.*

   Note: The camera overload alarm may sound briefly and then stop. This is normal and is not a cause for concern. However, if the alarm sounds continuously, even with no light entering the camera, something is wrong. Turn off the power and contact the factory for guidance.
3. Turn on the power at the computer and start the application software (WinView/32, for example).

Setting the Parameters

Note: The following procedure is based on WinView/32: you will need to modify it if you are using a different application. Basic familiarity with the WinView/32 software is assumed. If this is not the case, you may want to review the software manual or have it available while performing this procedure.

Set the software parameters as follows:

Controller|Camera tab page (Setup|Hardware)

- **Controller type:** ST-133
- **Controller version:** 4 or higher
- **Camera type:** Select array installed in your camera.
  MicroMAX:512BFT = EEV 512×512 FT CCD57
  MicroMAX:782Y = PID 582×782
  MicroMAX:782YHS = PID 582×782
  MicroMAX:1024B = EEV 1024×1024 CCD47_10
  MicroMAX:1300Y = PID 1030×1300
  MicroMAX:1300YHS = PID 1030×1300
  MicroMAX:1300YHS-DIF = PID 1030×1300
- **Shutter type:** None or Remote.
- **Readout mode:** Full frame, Interline or DIF depending on array type.

Detector Temperature (Setup|Detector Temperature…): -15°C for round camera heads or -45°C for rectangular camera heads. The temperature should drop steadily, reaching the set temperature in about ten minutes (typical). At that point the green **Temp Lock** LED on the rear of the ST-133 will light and there will be a **locked** indication at the computer monitor, indicating that temperature lock has been established. Note that some overshoot may occur. This could cause temperature lock to be briefly lost and then quickly re-established. If you are reading the actual temperature reported by the application software, there may be a small difference between the set and reported temperature when lock is established. This is

normal and does not indicate a system malfunction. Once lock is established, the temperature will be stable to within ±0.05°C.

Interface tab page (Setup|Hardware): High Speed PCI (or PCI(Timer))

Cleans and Skips tab page (Setup|Hardware): Default

Experiment Setup Main tab page (Acquisition|Experiment Setup…):

- **Exposure Time:** 100 ms
- **Accumulations & Number of Images:** 1

Easy Bin dialog box (Acquisition|Easy Bin…): Use this function to quickly set up change binning.

Experiment Setup ROI tab page (Acquisition|Experiment Setup…): Use this function to define the region of interest (ROI).

- **Image Mode:** Selected
- Clicking on **Full** loads the full size of the chip into the edit boxes.
- Clicking on **Store** will store the Pattern so it can be reused at another time.

Experiment Setup Timing tab page (Acquisition|Experiment Setup…):

- **Timing Mode:** Free Run
- **Shutter Control:** Normal
- **Safe Mode vs. Full Speed:** Safe (Asynchronous)

Acquisition Menu: Select **Video** if you have connected an RS-170 (or a CCIR) video monitor to the system and plan to use it for focusing or other operations. There will be a check next to "**Video**" to indicate that it is selected

Focusing

1. If you are using WinView/32 and the computer monitor for focusing, select **Focus** from the **Acquisition** menu. The shutter, if present, will open and successive images will be sent to the monitor as quickly as they are acquired. Because the time to acquire and read out an image varies directly with the size of the CCD, the observed frame rate will vary greatly depending on the CCD installed. With a short exposure time, it is not uncommon for the frame readout time to be significantly longer than the exposure time.

Note: If you are using WinView/32 and a video monitor for focusing, select the **Video Focus…** mode from the **Acquisition** menu. Then select a short exposure time (0.1 s), an Intensity Scaling setting of 4096, and 2x Zoom. With an MicroMAX:1300Y camera (1030×1300 pixels), set the Pan selector as required for the 756×486 subset of the array image you wish to use for focusing purposes. Select the center pan position if the camera is a MicroMAX:782Y (782×582 pixels) or a MicroMAX:512BFT (512×512 pixels). Begin data collection by selecting RUN on the **Interactive Camera Operation** dialog box. The shutter, if present, will open and successive images will be sent to the monitor as quickly as they are acquired, giving as close to continuous video as possible.

2. Adjust the lens aperture, intensity scaling, and focus for the best image as viewed on the monitor. Some imaging tips follow.

   a. Begin with the lens blocked off. Set the lens at the smallest possible aperture (largest f-stop number).

   b. Place a suitable target in front of the lens. An object with text or graphics works best. If working with a microscope, use any easily viewed specimen. It is generally not advisable to attempt fluorescence imaging during this *Getting Started* phase of operation.

   c. Adjust the intensity scaling and lens aperture until a suitable setting is found. The initial intensity scaling setting of 4096 assures that the image won't be missed altogether but could be dim. Once you've determined that the image is present, select a lower setting for better contrast. Check the brightest regions of the image to determine if the A/D converter is at full-scale. *The A/D converter is at full-scale when any part of the image is as bright as it can be.* Adjust the aperture to where it is just slightly smaller (higher f stop) than the setting where maximum brightness on any part of the image occurs.

   d. Set the focus adjustment of the lens for maximum sharpness in the viewed image.

   e. If the camera is mounted to a microscope, first be sure to have a clear, focused image through the eyepiece. Then divert the light to the camera and lower the illuminating light intensity.

      - To adjust the parfocality on an F-mount system, begin collecting images with a short exposure time and focus the light on the camera by rotating the ring on the Diagnostic Instruments relay lens without touching the main focusing knobs on the microscope.

      - In the case of a camera with an F-mount lens adapter, focusing is normally done by means a focus adjustment on the relay-lens adapter.

      - On a C-mount system, the camera should be very close to parfocal, although some C-mounts will be adjustable using setscrews on the microscope to secure the adapter slightly higher or lower in position.

   f. In the case of a camera with an F-mount, the adapter itself also has a focus adjustment. If necessary, this focus can be changed to bring the image into range of the lens focus adjustment. The lens-mount adjustment is secured by four setscrews as shown in Figure 12. To change the focus setting, proceed as follows.

      - Loosen the setscrews with a 0.050" Allen wrench. Do not remove the screws; loosen them just enough to allow the lens mount to be adjusted.

      - Rotate the lens mount as required to bring the focus within range of the lens focus adjustment.

      - Tighten the setscrews loosened above.

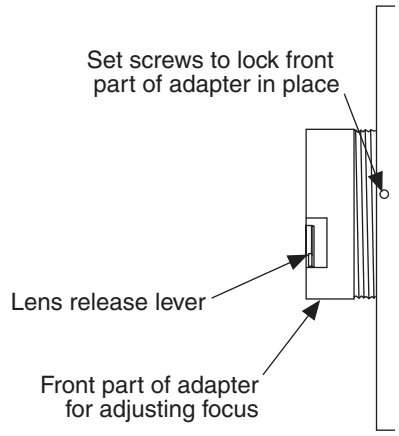


Figure 12. F-mount Focus Adjustment

Acquiring Data

Once optimum focus and aperture have been achieved, you can switch from **Focus** (or **Video Focus**) mode to standard data-acquisition operation as determined via the **Experiment Setup** dialog box. (In WinView/32, you might want to begin with Free Run Asynchronous (Safe Mode) operation while gaining basic system familiarity.)

This completes *First Light*. If the system functioned as described, you can be reasonably sure it has arrived in good working order. In addition, you should have a basic understanding of how the system hardware is used. Other topics, which could be quite important in certain situations, are discussed in the following chapters. See the appropriate application software manual for information on using the software to control the system.

Summary

If the system functioned as described in "First Light", you can be reasonably sure it has arrived in good working order. In addition, you should have a basic understanding of how the system hardware is used. Other topics, which are important under certain conditions, are discussed in the following chapters. See the appropriate application software manual for information on using the software to control the system.

Chapter 5
Timing Modes

The Princeton Instruments MicroMAX system has been designed to allow the greatest possible flexibility when synchronizing data collection with an experiment.

The chart below lists the timing mode combinations. Use this chart in combination with the detailed descriptions in this chapter to determine the optimal timing configuration.

Mode	Shutter
Free Run	Normal
External Sync	Normal
External Sync	PreOpen
Continuous Cleans	Normal
Continuous Cleans	PreOpen

Table 2. Camera Timing Modes

Full Speed or Safe Mode

The WinView/32 Experiment Setup **Timing** tab page allows the user to choose **Full Speed** (Synchronous) or **Safe Mode** (Asynchronous). Figure 13 is a flowchart comparing the two modes. In Full Speed (Synchronous) operation, the MicroMAX runs according to the timing of the experiment, with no interruptions from the computer. In Safe Mode operation, the computer processes each frame as it is received. The MicroMAX cannot collect the next frame until the previous frame has been completely processed.

Full Speed operation is primarily for collecting "real-time" sequences of experimental data, where timing is critical and events cannot be missed. Once the MicroMAX is sent the Start Acquisition command (STARTACQ) by the computer, all frames are collected without further intervention from the computer. The advantage of this timing mode is that timing is controlled completely through hardware. A drawback to this mode is that the computer will only display frames when it is not performing other tasks. Image display has a lower priority, so the image on the screen may lag several images behind. *A video monitor connected to the VIDEO output will always display the current image.* A second drawback is that a data overrun may occur if the number of images collected exceeds the amount of allocated RAM or if the computer cannot keep up with the data rate.

Safe Mode operation is primarily useful for experiment setup, including alignment and focusing, when it is necessary to have the most current image displayed on the screen. It is also useful when data collection must be coordinated with external devices such as

external shutters and filter wheels. As seen in Figure 13, in Safe Mode operation, the computer controls when each frame is taken. After each frame is received, the camera sends the Stop Acquisition command to the camera, instructing it to stop acquisition. Once that frame is completely processed and displayed, another Start Acquisition command is sent from the computer to the camera, allowing it to take the next frame. Display is therefore, at most, only one frame behind the actual data collection.

One disadvantage of the Safe (Asynchronous) mode is that events may be missed during the experiment, since the MicroMAX is disabled for a short time after each frame.

Standard Timing Modes

The basic MicroMAX timing modes are Free Run, External Sync, and External Sync with Continuous Cleans. These timing modes are combined with the Shutter options to provide the widest variety of timing modes for precision experiment synchronization.

The shutter options available include Normal, PreOpen, Disable Opened or Disable Closed. Disable simply means that the shutter will not operate during the experiment. Disable closed is useful for making dark charge measurements, or when no shutter is present in the system. PreOpen, available in the External Sync mode, opens the shutter as soon as the MicroMAX is ready to receive an External Sync pulse. This is required if the time between the External Sync pulse and the event is less than a few milliseconds, the time it takes the shutter to open.

The shutter timing is shown in the timing diagrams that follow. Except for Free Run, where the modes of shutter operation are identical, both Normal and PreOpen lines are shown in the timing diagrams and flowchart.

The timing diagrams are labeled indicating the exposure time (t_{exp}), shutter compensation time (t_c), and readout time (t_R). See Chapter 6 for additional information.

Free Run

In the Free Run mode the controller does not synchronize with the experiment in any way. The shutter opens as soon as the previous readout is complete, and remains open for the exposure time, t_{exp}. Any External Sync signals are ignored. This mode is useful for experiments with a constant light source, such as a CW laser or a DC lamp. Other experiments that can utilize this mode are high repetition studies, where the number of shots that occur during a single shutter cycle is so large that it appears to be continuous illumination.

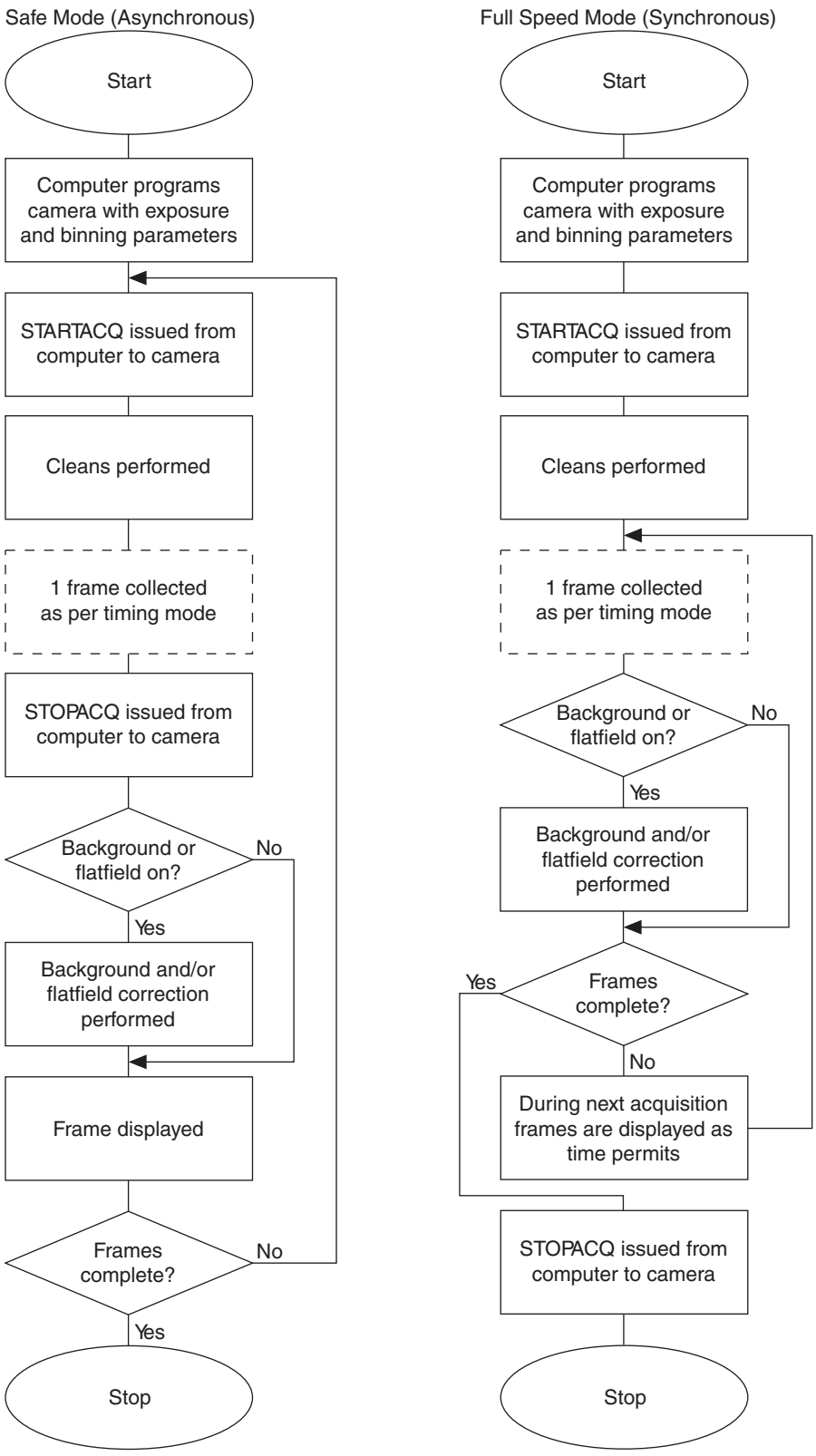


Figure 13. Chart of Full Speed (Synchronous) and Safe (Asynchronous) Operation

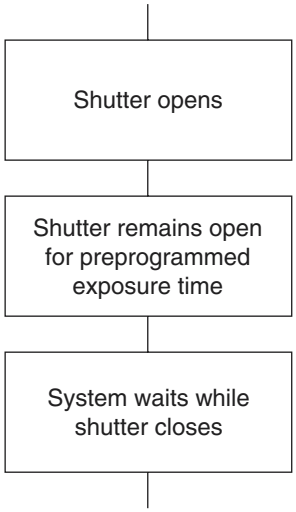


Figure 14. Free Run Timing Chart (part of the chart in Figure 13)

Other experimental equipment can be synchronized to the MicroMAX system by using the $\overline{\text{SCAN}}$ (NOTSCAN) signal. This TTL output for synchronous operation is shown in Figure 15.

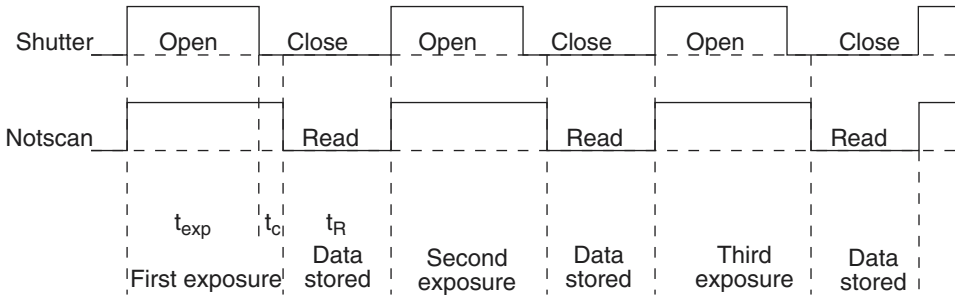


Figure 15. Free Run Timing Diagram

External Sync

In this mode all exposures are synchronized to an external source. As shown in the flowchart, Figure 16, this mode can be used in combination with Normal or PreOpen Shutter operation. In Normal Shutter mode, the controller waits for an External Sync pulse, then opens the shutter for the programmed exposure period. As soon as the exposure is complete, the shutter closes and the CCD array is read out. The shutter requires 5-10 msec to open completely, depending on the model of shutter. (Shutter compensation time is discussed in Chapter 6.)

Since the shutter requires up to 10 msec to fully open, the External Sync pulse provided by the experiment must precede the actual signal by at least that much time. If not, the shutter will not be open for the duration of the entire signal, or the signal may be missed completely.

Also, since the amount of time from initialization of the experiment to the first External Sync pulse is not fixed, an accurate background subtraction may not be possible for the first readout. In multiple-shot experiments this is easily overcome by simply discarding the first frame.

In the PreOpen Shutter mode, on the other hand, shutter operation is only partially synchronized to the experiment. As soon as the controller is ready to collect data the shutter opens. Upon arrival of the first External Sync pulse at the MicroMAX, the shutter remains open for the specified exposure period, closes, and the CCD is read out. As soon as readout is complete the shutter reopens and waits for the next frame.

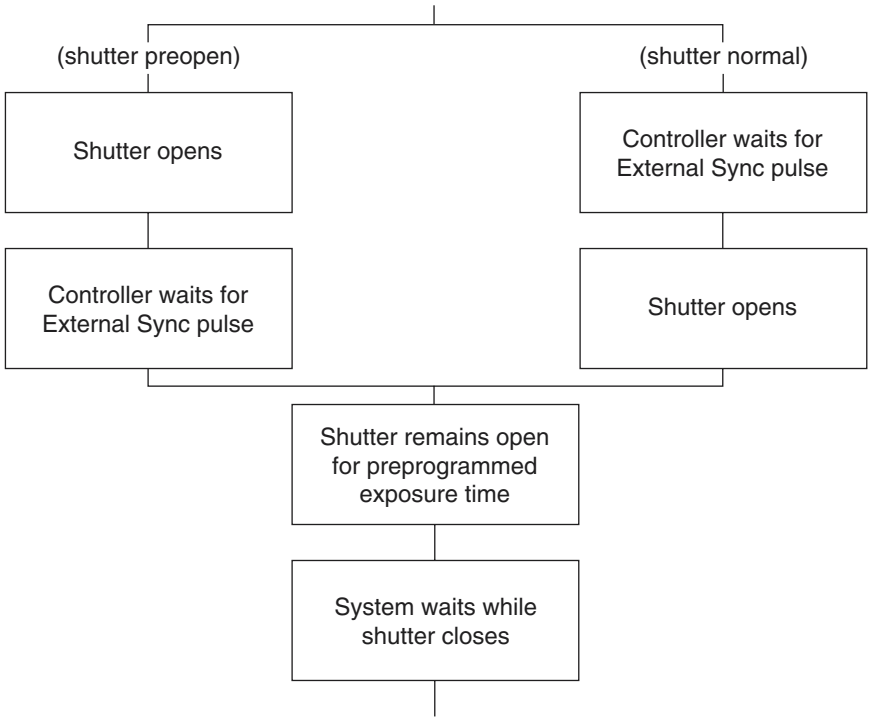

(shutter preopen)
(shutter normal)
Shutter opens
Controller waits for External Sync pulse
Controller waits for External Sync pulse
Shutter opens
Shutter remains open for preprogrammed exposure time
System waits while shutter closes

Figure 16. Chart Showing Two External Sync Timing Options

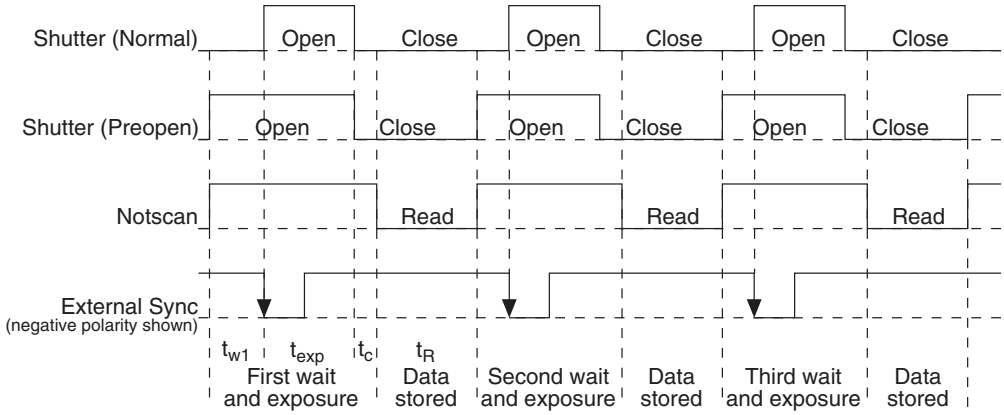


Figure 17. External Sync Timing Diagram

The PreOpen mode is useful in cases where an External Sync pulse cannot be provided 5-10 msec before the actual signal occurs. Its main drawback is that the CCD is exposed to any ambient light while the shutter is open between frames. If this ambient light is constant, and the triggers occur at regular intervals, this background can also be subtracted, providing that it does not saturate the CCD. As with the Normal Shutter mode, accurate background subtraction may not be possible for the first frame.

Also note that, in addition to signal from ambient light, dark charge accumulates during the "wait" time (t_w). Any variation in the external sync frequency also affects the amount of dark charge, even if light is not falling on the CCD during this time.

Note: If EXT SYNC is still active at the end of the readout, the hardware will interpret this as a second sync pulse, and so on.

External Sync with Continuous Cleans

The third timing mode available with the MicroMAX camera is called Continuous Cleans. In addition to the standard "cleaning" of the array, which occurs after the controller is enabled, Continuous Cleans will remove any charge from the array until the moment the External Sync pulse is received.

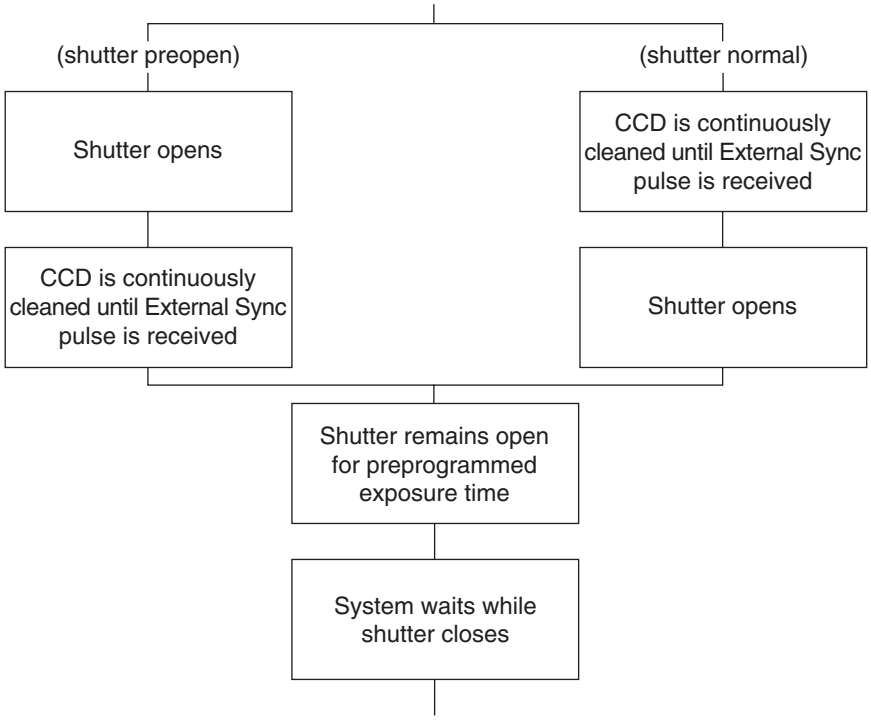

(shutter preopen)
(shutter normal)
Shutter opens
CCD is continuously cleaned until External Sync pulse is received
CCD is continuously cleaned until External Sync pulse is received
Shutter opens
Shutter remains open for preprogrammed exposure time
System waits while shutter closes

Figure 18. Continuous Cleans Flowchart

Once the External Sync pulse is received, cleaning of the array stops as soon as the current row is shifted, and frame collection begins. With Normal Shutter operation the shutter is opened for the set exposure time. With PreOpen Shutter operation the shutter is open during the continuous cleaning, and once the External Sync pulse is received the shutter remains open for the set exposure time, then closes. If the vertical rows are shifted midway when the External Sync pulse arrives, the pulse is saved until the row shifting is completed, to prevent the CCD from getting "out of step." As expected, the response latency is on the order of one vertical shift time, from 1-30 μsec depending on the array. This latency does not prevent the incoming signal from being detected, since photo generated electrons are still collected over the entire active area. However, if the signal arrival is coincident with the vertical shifting, image smearing of up to one pixel is possible. The amount of smearing is a function of the signal duration compared to the single vertical shift time.

Note: If EXT SYNC is still active at the end of the readout, the hardware will interpret this as a second sync pulse, and so on.

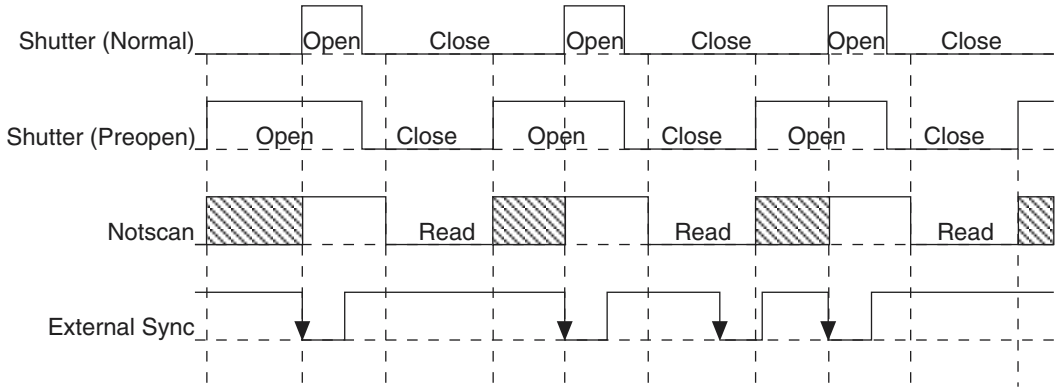


Figure 19. Continuous Cleans Timing Diagram

Frame Transfer Operation

In frame transfer operation, half the CCD is used for sensing light and the other half for storage and readout. Not all CCD arrays are capable of readout in this mode, as it requires that charge be shifted independently in the two halves of the array. *See Chapter 6 for a detailed discussion of readout in the frame-transfer mode operation; the primary focus of this section is frame-transfer timing.*

There are two timing options available in frame transfer mode, Free Run and External Sync. Both are similar to their counterparts in full frame (standard) operation, except that in frame transfer operation a shutter is not generally used. Because there is no shutter (or the shutter is only closed after the camera has collected a series of frames), shutter Normal, PreOpen, or Disable have no physical meaning here. The exposure half of the array sees light continuously. The *actual exposure time* is the time between data transfers from the exposure half of the array to the storage half of the array, and may be longer than the programmed exposure, t_{exp}. Data transfer from the exposure half of the array to the storage half occurs very quickly at the start of each read. During the read, the stored data is shifted to the array's output port, the same as in standard operation.

In Free Run frame-transfer mode operation, half of the array is exposed for the set exposure time (t_{exp}). Then the data transfer to the storage half of the array takes place, marking the start of the read and the beginning of a new exposure.

In External Sync frame-transfer mode operation, the camera reads out one frame for every External Sync pulse received, providing the frequency of the External Sync pulse doesn't exceed the maximum rate possible with the system. Other than for the first readout, initiated by starting acquisition, a Sync Pulse must be detected before the subsequent readout can occur.

Note: If EXT SYNC is still active at the end of the readout, the hardware will interpret this as a second sync pulse, and so on.

If operating without a shutter, the actual exposure time is set by the period of the sync signal. There is one exception, if the programmed exposure time is less than the readout time, then the actual exposure time is simply equal to $t_{R,}$the readout time (marked by

$\overline{SCAN}$ low). More specifically, if the readout time, t_R, is greater than the sum of t_{w1}, the time the controller waits for the first External Sync pulse, plus t_{exp}, the programmed exposure time, plus t_c, the shutter compensation time, then the actual exposure time will equal t_R. If an External Sync pulse is detected during each read, frames will follow one another as rapidly as possible as shown in Figure 20. *In these figures, Shutter Monitor indicates the programmed exposure time. If a shutter were present and active, it would also be the actual exposure time.*

Prior to the first readout, clean cycles are performed on the array. When the software issues a Start Acquisition command, the first readout is generated in hardware and the rapid data transfer from the exposure half of the array to the storage half of the array occurs (marking the beginning of the first exposure). The initial data read are discarded because they are not meaningful. The first exposure continues until the next data transfer, which occurs at the beginning of the next readout, 50 ns after the first readout ends. The data acquired during the first exposure is then read out. This pattern continues for the duration of the experiment so that, during each frame, the data acquired during the previous frame is read out.

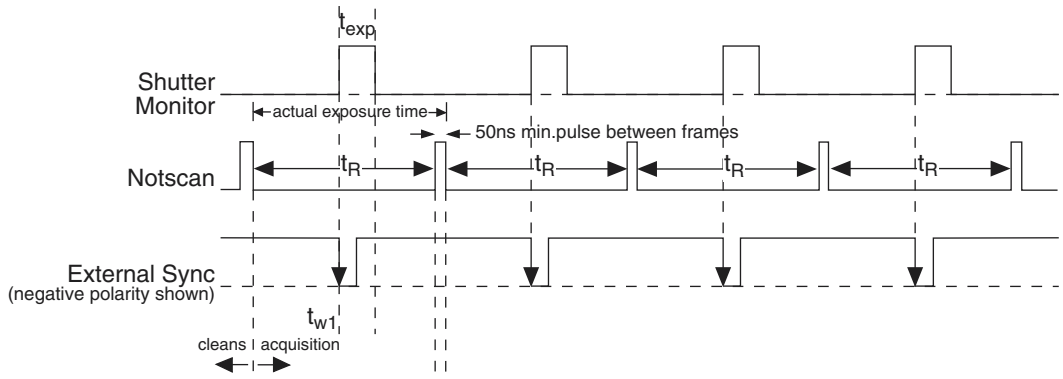


Figure 20. Frame Transfer where $t_{w1} + t_{exp} + t_c < t_R$

Figure 21 shows the case where the programmed storage time is greater than the time required to read out the storage half of the array, that is, where $t_{w1} + t_{exp} + t_c > t_R$. In this case, the programmed exposure time will dominate in determining the actual exposure time. In the situation depicted in Figure 21, the External Sync pulse arrives during the readout. As always, the External Sync pulse must be detected before the next readout can occur. However, there is no requirement as to when it must be applied or even that it be periodic. The timing of the External Sync pulse is entirely at the user's discretion. In Figure 22, the External Sync pulse is shown arriving after the read. Detection of the External Sync pulse enables a new readout to occur on completion $t_{exp} + t_c$.

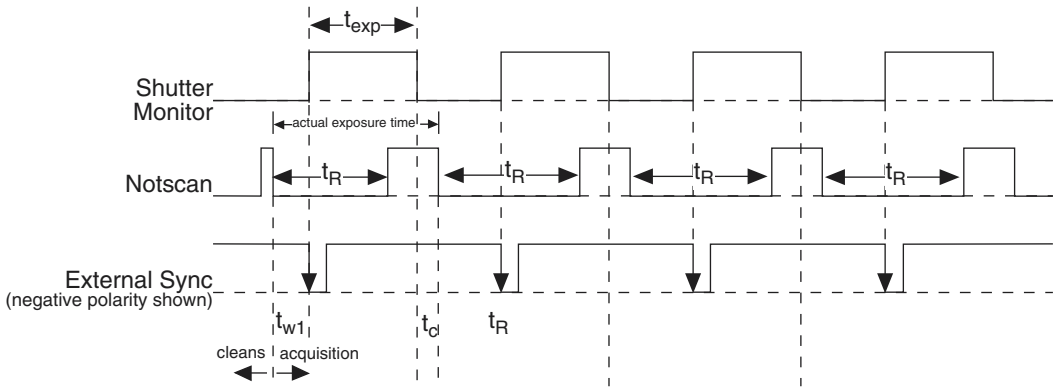


Figure 21. Frame Transfer where $t_{w1} + t_{exp} + t_c > t_R$

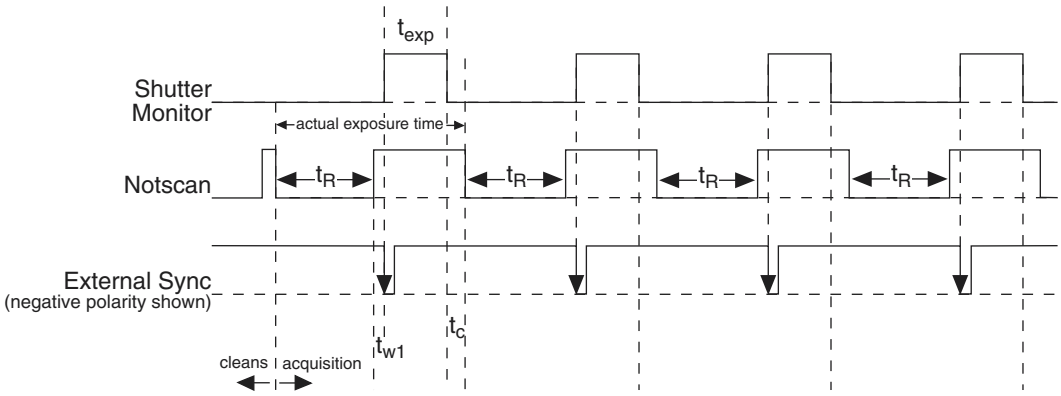


Figure 22. Frame Transfer where Pulse arrives after Readout

Interline Operation

Operating Modes

It is important to note that an interline chip can operate in either of two operating modes, overlapped or non-overlapped. The operating mode is always overlapped unless the exposure time is shorter than the readout time, in which case non-overlapped operation is automatically selected by the controlling software. Because overlapped operation is faster, to achieve the fastest possible operation, it is generally preferable to operate overlapped if possible. Thus there may be situations where ***increasing the exposure time*** slightly will cause the camera to switch from non-overlapped to overlapped operation. When this happens, the video may blank for a moment as the unit is reprogrammed, and then reappear with approximately double the frame rate that was available when it was operating non-overlapped. Detailed discussions of how the interline camera works and the implications for operation follow.

As stated before, there are two basic operating modes, overlapped and non-overlapped:

- **Overlapped:** When the camera is operated in the overlapped mode, readout begins at the end of the exposure time and a new exposure is initiated immediately. This mode allows the fastest possible speed. And, because the charge only has to transfer to the adjacent row, there is no smearing.

- **Non-overlapped:** This operation mode is automatically selected by the controlling software when the exposure time is less than the readout time. In non-overlapped operation, the image is transferred to the storage cells at the end of the exposure time and no further accumulation occurs (the imaging cells are switched off). The accumulated charge on each storage cell is transferred out of the CCD array, amplified, and sent to the controller as an analog signal, where it is digitized prior to transfer to the computer.

Timing Options in Overlapped Readout Mode

Interline CCD arrays have columns of imaging cells alternating with columns of storage cells. During readout, the charge stored in the photo-sensitive imaging cells move only one row to the adjacent storage cells. From there they move downwards to the readout register and from there to the output node. This scheme serves to allow high speeds, no smearing and shutterless operation, a distinct advantage over frame-transfer sensors where the cell contents can be contaminated by the charge in other cells as data is moved across the CCD and under the mask.

There are two timing options available in the overlapped mode, Free Run and External Sync. (**None** should be the Shutter Type selection if using WinView/32 software and operating without a shutter.) In both Free Run and External Sync operation, the array photosensors see light continuously. The *actual exposure time* is the time between data transfers from a photo-sensitive imaging cell to the adjacent storage cell, and may be longer than the programmed exposure, t_{exp}. Data transfer from the photo-sensitive imaging cells to the storage cells occurs very quickly at the start of each readout. During the read, the stored data is shifted to the array's readout register and from there to the output node.

- In Free Run overlapped mode operation, the imaging cells are exposed for the set exposure time (t_{exp}). Then the data transfer to the storage cells takes place, marking the start of the read and the beginning of a new exposure.
- In the External Sync mode, *overlapped operation only is provided.* The camera reads out one frame for every External Sync pulse received, providing the frequency of the External Sync pulse does not exceed the maximum rate possible with the system. A sync pulse must be detected before the subsequent readout can occur. If operating without a shutter, the actual exposure time is set by the period of the sync signal. There is one exception.

  If the programmed exposure time is less than the readout time in the External Sync mode, then the actual exposure time is simply equal to t_R, the readout time (marked by $\overline{SCAN}$ low). More specifically, if the readout time, t_R, is greater than the sum of t_{w1}, the time the controller waits for the first External Sync pulse, plus t_{exp}, the programmed exposure time, plus t_c, the shutter compensation time (zero with **None** selected as the Shutter type), then the actual exposure time will equal t_R. If an External Sync pulse is detected during each read, frames will follow one another as rapidly as possible as shown in Figure 23. In these figures, Shutter Monitor indicates the *programmed* exposure time. If a shutter were present and active, it would also be the *actual* exposure time.

  Before the first readout, clean cycles are performed on the array. When the software issues a Start Acquisition command, the first exposure begins. Time counting of the programmed Exposure Time begins when the sync pulse arrives

at the Ext Sync connector. The exposure ends on completion of the programmed Exposure Time. Then the data acquired during the first exposure is read out while the next frame of data is being acquired. This pattern continues for the duration of the experiment so that, during each frame, the data acquired during the previous frame is read out.

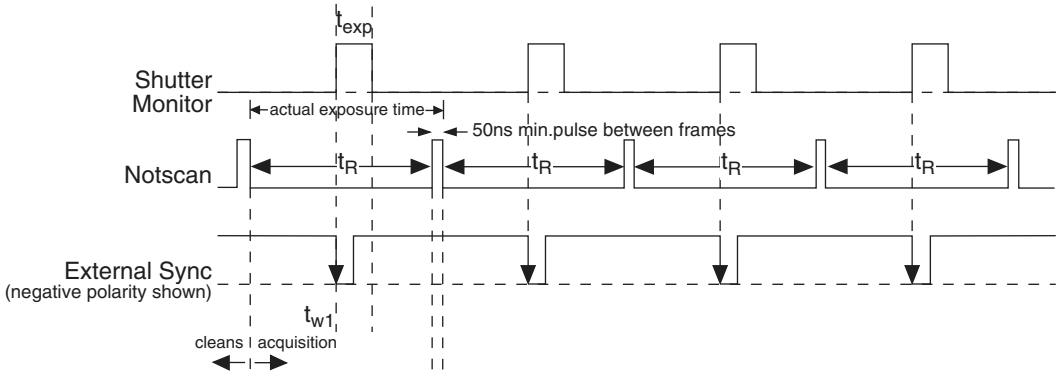


Figure 23. Overlapped Mode where $t_{w1} + t_{exp} + t_c < t_R$

Figure 24 shows the case where the programmed exposure time is greater than the time required to read out the storage half of the array, that is, where $t_{w1} + t_{exp} + t_c > t_R$. In this case, the programmed exposure time will dominate in determining the actual exposure time. In the situation depicted in Figure 24, the External Sync pulse arrives during the readout. As always, the External Sync pulse must be detected before the next readout can occur. However, there is no requirement as to when it must be applied or even that it be periodic. The timing of the External Sync pulse is entirely at the user's discretion. In Figure 25, the External Sync pulse is shown arriving after the read. Detection of the External Sync pulse enables a new readout to occur on completion $t_{exp} + t_c$.

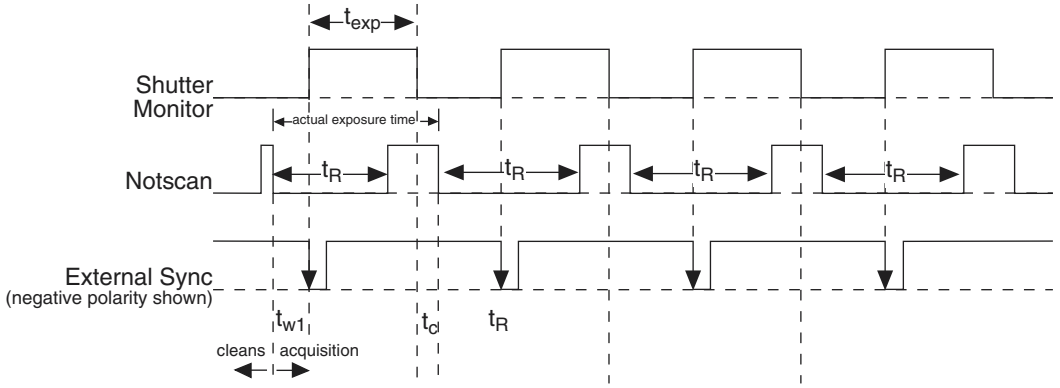


Figure 24. Overlapped Mode where $t_{w1} + t_{exp} + t_c > t_R$

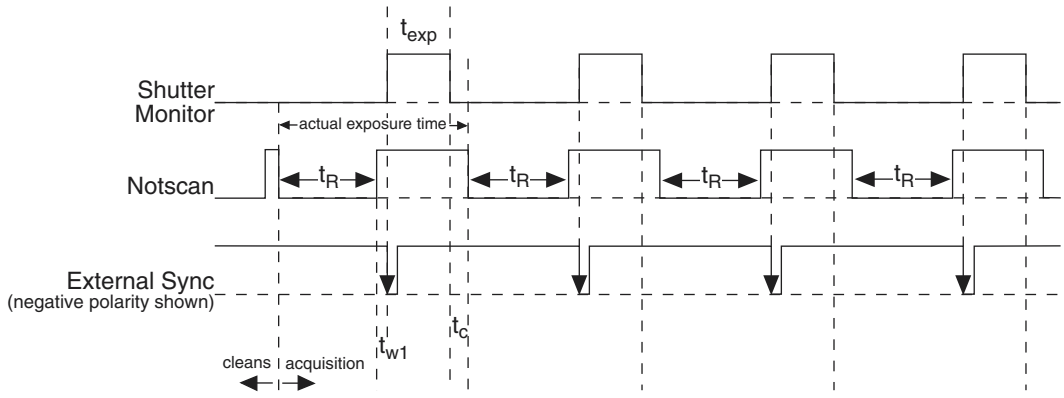


Figure 25. Overlapped Mode where Pulse arrives after Readout

Chapter 6
Exposure and Readout

Before each image from the CCD array appears on the computer screen, it must first be read, digitized, and transferred to the computer. Figure 26 is a block diagram of the image-signal path.

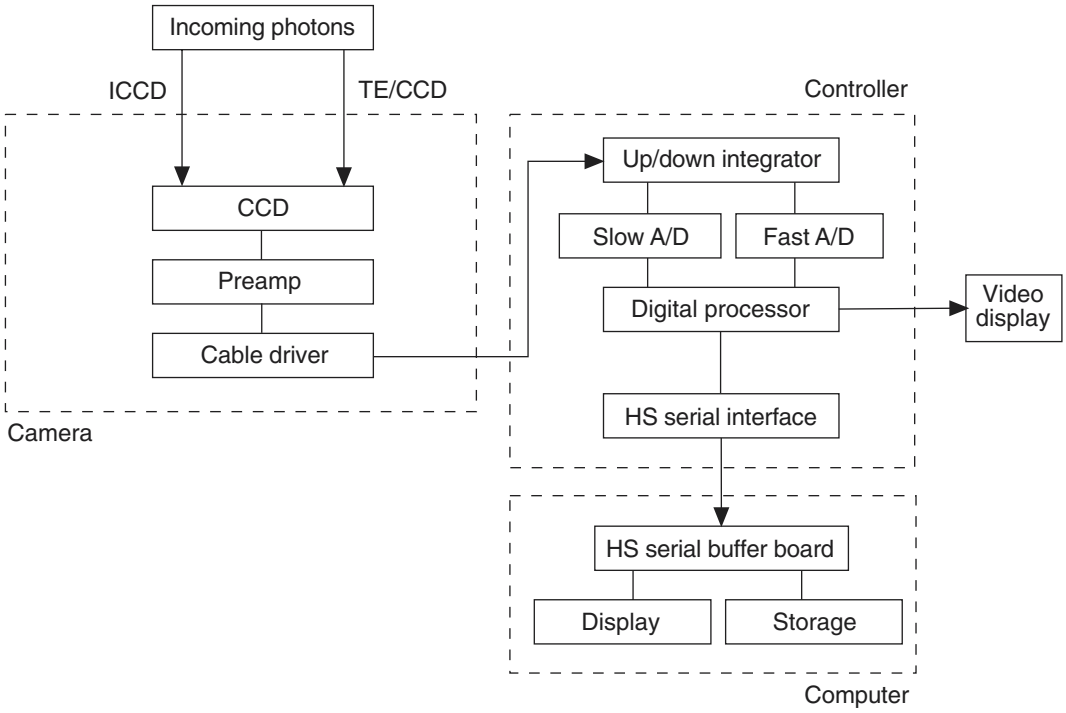


Figure 26. Block Diagram of Light Path in System

The remainder of this chapter describes the exposure, readout, and digitization of the image. Included are descriptions of binning for imaging applications and the specialized MicroMAX timing modes.

Exposure

Charge coupled devices can be roughly thought of as a two-dimensional grid of individual photodiodes (called pixels), each connected to its own charge storage "well." Each pixel senses the intensity of light falling on its collection area, and stores a proportional amount of charge in its associated "well". Once charge accumulates for the specified exposure time, the charge in the image pixels are moved to a different location. Depending on the CCD array type, the pixels are read out to a serial register or shifted under a masked area or into storage cells and then read out to a serial register.

CCD arrays perform three essential functions: photons are transduced to electrons, integrated and stored, and finally read out. CCDs are very compact and rugged.

Unintensified, uncoated CCDs can withstand direct exposure to relatively high light levels, magnetic fields and RF radiation. They are easily cooled and can be precisely temperature controlled to within a few tens of millidegrees.

Because CCD arrays, like film and other media, are always sensitive to light, light must not be allowed to fall on the array during readout. Unintensified full-frame CCD cameras like the MicroMAX use a mechanical shutter to prevent light from reaching the CCD during readout. ICCD (intensified) cameras use an image intensifier to gate the light on and off.

The software allows the user to set the length of time the camera is allowed to integrate the incoming light. This is called the exposure time. During each scan, the shutter or intensifier is enabled for the duration of the exposure period, allowing the pixels to register light.

Exposure with an Interline Array

Interline transfer CCDs contain alternate columns of imaging and storage cells that work in pairs. Light impinging on the imaging cells cause a charge buildup. As previously explained, the operating mode is always overlapped unless the exposure time is shorter than the readout time, in which case non-overlapped operation is automatically selected.

Note: The storage cells of an interline array are quite light-insensitive (the ratio of the light sensitivity of the storage cells, which are masked, to the light sensitivity of the imaging cells is ~4000:1). However, even with a rejection ratio of ~4000:1, there may be situations where this may not be sufficient to prevent light leakage from significantly affecting the data. That this is so becomes apparent when the on/off time factors are considered. In an experiment with a very short exposure compared to the readout rate, the ratio of the readout time to the exposure time may easily be of the same order as the rejection ratio of the interline array storage cells. Where this is the case, the signal buildup in the storage cells during the readout time may equal the signal transferred from the imaging cells to the storage cells at the end of the exposure time. The effect of this signal will be to cause data smearing. The only solutions to this problem at this time are to increase the exposure time to where the effect is insignificant, use a shutter, or to use a gated light source.

Exposure with a Mechanical Shutter

For some CCD arrays, the MicroMAX uses a mechanical shutter to control exposure of the CCD. The diagram in Figure 27 shows how the exposure period is measured. The $\overline{\text{SCAN}}$ output provided at the ST-133 Analog/Control panel can be used to monitor the exposure and readout cycle (t_R). This signal is also shown in Figure 27. The value of t_c is shutter type dependent, and will be configured automatically for MicroMAX systems shipped with an internal shutter.

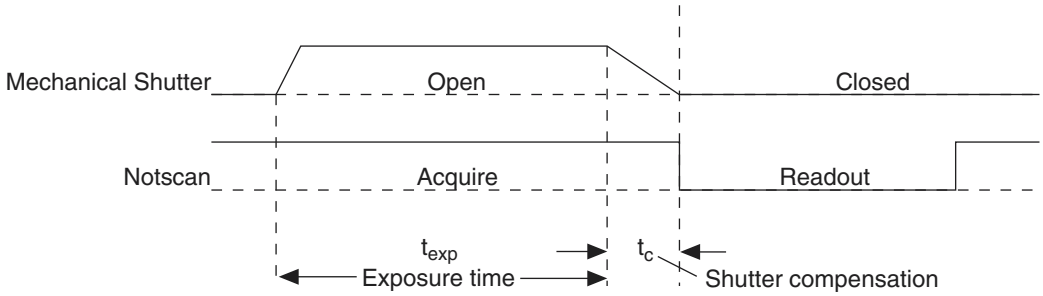


Figure 27. CCD Exposure with Shutter Compensation

$\overline{\text{SCAN}}$ is low during readout, high during exposure, and high during shutter compensation time.

Since most shutters behave like an iris, the opening and closing of the shutter will cause the center of the CCD to be exposed slightly longer than the edges. It is important to realize this physical limitation, particularly when using short exposures.

Exposure with an Image Intensifier

Although the standard MicroMAX camera is not intensified, it is possible to connect it to a lens-coupled intensifier. Contact the factory if you are interested in more information about operating an intensified version of the MicroMAX system.

Continuous Exposure (no shuttering)

Unlike video rate CCD cameras, slow scan scientific cameras require a shutter to prevent "smearing" of features during readout or transfer to a masked area or storage cells. Smearing occurs during readout because charge is moved horizontally or vertically across the surface of the CCD while charge continues to accumulate on the array. As the result, the image will be blurred along one direction only.

The fraction of total signal due to smearing is the ratio of the amount of time spent shifting divided by the exposure time between frames. Faster shifting and/or longer exposure times will minimize this effect. Note that while 1% smear is insignificant in an 8-bit camera (256 gray levels), in a 12-bit camera (over 4,000 gray levels) 1% smearing is over 40 counts, enough to obscure faint features in a high dynamic range image.

Full-Frame

For full-frame CCDs, the MicroMAX camera is usually equipped with an integral shutter. If a full-frame MicroMAX is being operated without a shutter, smearing can be avoided by ensuring that no light falls on the CCD during readout. If the light source can be controlled electronically via the $\overline{\text{SCAN}}$ or SHUTTER Monitor output, the CCD can be read out in darkness.

Frame Transfer

For frame transfer CCDs, image smearing may occur, depending on the exact nature of the experiment. Smearing occurs only if the CCD is illuminated during shifting. In the case of lens-coupled intensified cameras (ICCDs), this effect can be eliminated by using a fast phosphor and gating the intensifier at the same frame rate as the CCD.

Interline

For interline CCDs, image smearing may occur due to a small amount of light leaking through to the storage cells during the readout time. In the case of lens-coupled intensified cameras (ICCDs), this effect can be eliminated by using a fast phosphor and gating the intensifier at the same frame rate as the CCD.

Saturation

When signal levels in some part of the image are very high, charge generated in one pixel may exceed the "well capacity" of the pixel, spilling over into adjacent pixels in a process called "blooming." In this case a more frequent readout is advisable, with signal averaging to enhance S/N (Signal-to-Noise ratio) accomplished through the software.

For signal levels low enough to be readout-noise limited, longer exposure times, and therefore longer signal accumulation in the CCD, will improve the S/N ratio approximately linearly with the length of exposure time. There is, however, a maximum time limit for on-chip averaging, determined by either the saturation of the CCD by the signal or the loss of dynamic range due to the buildup of dark charge in the pixels (see below).

Dark Charge

Dark charge (or dark current) is the thermally induced buildup of charge in the CCD over time. The statistical noise associated with this charge is known as dark noise. Dark charge values vary widely from one CCD array to another and are exponentially temperature dependent. At the typical operating temperature of a round head camera, for example, dark charge is reduced by a factor of ~2 for every 6º reduction in temperature.

With the light into the camera completely blocked, the CCD will collect a dark charge pattern, dependent on the exposure time and camera temperature. The longer the exposure time and the warmer the camera, the larger and less uniform this background will appear. Thus, to minimize dark-charge effects, you should operate with the lowest CCD temperature possible.

Note: Do not be concerned about either the DC level of this background or its shape unless it is very high, i.e., > 1000 counts. What you see is not noise. It is a fully subtractable readout pattern. Each CCD has its own dark charge pattern, unique to that particular device. Simply acquire and save a dark charge "background image" under conditions identical to those used to acquire the "actual" image. Subtracting the background image from the actual image will significantly reduce dark-charge effects.

Array Readout

In this section, a simple 6 × 4 pixel CCD is used to demonstrate how charge is shifted and digitized. As described below, two different types of readout are available. Full frame readout, for full frame CCDs, reads out the entire CCD surface at the same time. Frame transfer operation assumes half of the CCD is for data collection and half of the array is a temporary storage area.

Full Frame

The upper left drawing in Figure 28 represents a CCD after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This section explains readout at full resolution, where every pixel is digitized separately.

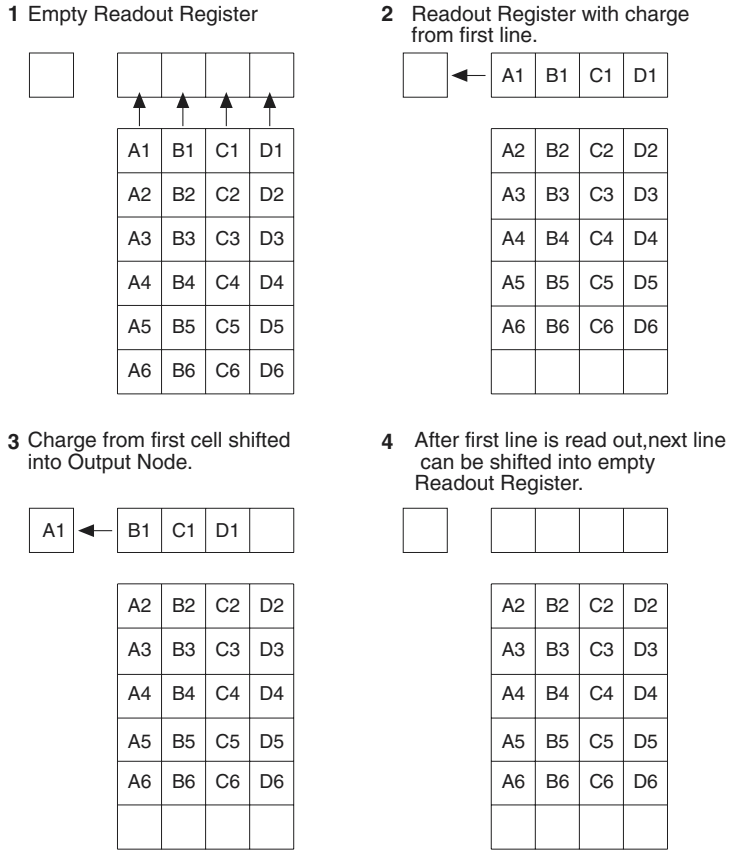

1 Empty Readout Register
2 Readout Register with charge from first line.
3 Charge from first cell shifted into Output Node.
4 After first line is read out,next line can be shifted into empty Readout Register.
A1 B1 C1 D1
A2 B2 C2 D2
A3 B3 C3 D3
A4 B4 C4 D4
A5 B5 C5 D5
A6 B6 C6 D6

Figure 28. Full Frame at Full Resolution

Readout of the CCD begins with the simultaneous shifting of all pixels one column toward the “shift register,” in this case the column on the far right. The shift register is a single line of pixels along one side of the CCD, not sensitive to light and used for readout only. Typically the shift register pixels hold twice as much charge as the pixels in the imaging area of the CCD.

After the first column is moved into the shift register, the charge now in the shift register is shifted toward the output node, located at one end of the shift register. As each value is “emptied” into this node it is digitized. Only after all pixels in the first column are

digitized is the second column moved into the shift register. The order of shifting in our example is therefore D6, C6, B6, A6, D5, C5, B5, A5, D4....

After charge is shifted out of each pixel the remaining charge is zero, meaning that the array is immediately ready for the next exposure.

Below are the equations that determine the rate at which the CCD is read out. Tables of values for CCDs supported at the time of the printing of this manual also appear below.

The time needed to take a full frame at full resolution is:

$$t_R + t_{exp} + t_c \quad (1)$$

where

t_R is the CCD readout time,

t_{exp} is the exposure time, and

t_c is the shutter compensation time.

The readout time is approximately given by:

$$t_R = [N_x \cdot N_y \cdot (t_{sr} + t_v)] + (N_x \cdot t_i) \quad (2)$$

where

N_x is the smaller dimension of the CCD

N_y is the larger dimension of the CCD

t_{sr} is the time needed to shift one pixel out of the shift register

t_v is the time needed to digitize a pixel

t_i is the time needed to shift one line into the shift register

(t_s, the time needed to discard a pixel, appears below and in later equations)

The readout time for a 1024x1024 full-frame CCD array is provided in Table 3 below.

CCD Array	1 MHz Readout Time
MicroMAX:1024B EEV CCD47-10 1024x1024	1.1 sec. for full frame

Table 3. Approximate Readout Time for the Full-Frame CCD Array

A subsection of the CCD can be read out at full resolution, sometimes dramatically increasing the readout rate while retaining the highest resolution in the region of interest (ROI). To approximate the readout rate of an ROI, in Equation 2 substitute the x and y dimensions of the ROI in place of the dimensions of the full CCD. Some overhead time, however, is required to read out and discard the unwanted pixels.

Frame Transfer

The MicroMAX fully supports frame transfer readout. Operation in this mode is very similar to the operation of video rate cameras. Half of the CCD is exposed continuously, raising the exposure duty cycle to nearly 100%. The other half of the CCD is masked to prevent exposure, and it is here that the image is "stored" until it can be read out. Figure 29 shows the readout of a masked version of our sample 4 × 6 CCD. The shading represents the masked area (masking is on the array).

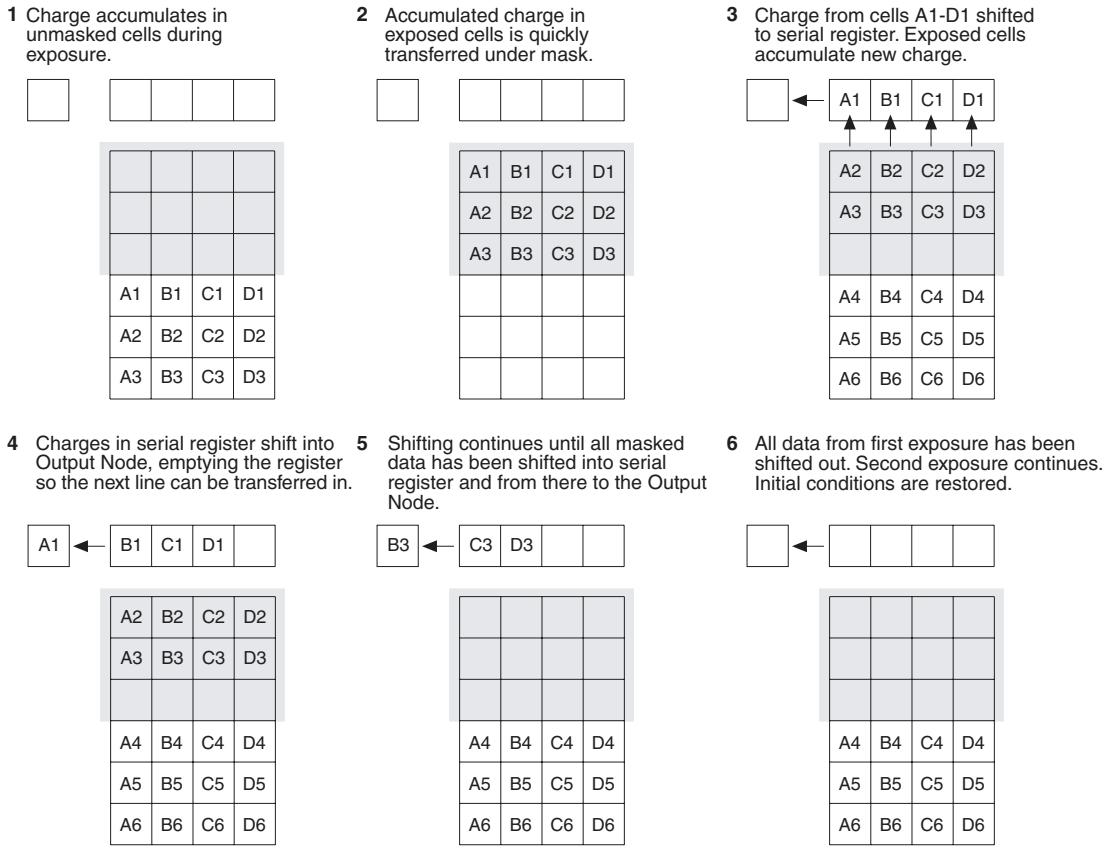

1 Charge accumulates in unmasked cells during exposure.
2 Accumulated charge in exposed cells is quickly transferred under mask.
3 Charge from cells A1-D1 shifted to serial register. Exposed cells accumulate new charge.
4 Charges in serial register shift into Output Node, emptying the register so the next line can be transferred in.
5 Shifting continues until all masked data has been shifted into serial register and from there to the Output Node.
6 All data from first exposure has been shifted out. Second exposure continues. Initial conditions are restored.

Figure 29. Frame Transfer Readout

Only the exposed region collects charge. At the end of the exposure, the charge is quickly shifted into the masked region. Since the shifting is accomplished in a short time, i.e., a few milliseconds, the incident light causes only minimal "smearing" of the signal. While the exposed region continues collecting data, the masked region is read out and digitized. The percentage of smearing can be determined by dividing the time needed to shift all rows from the imaging area by the exposure time. See the equation below.

$$\frac{N_x t_i}{t_{exp}}$$

CCD Array	1 MHz Readout Time
MicroMAX:512BFT EEV CCD57-10 512 x 512	0.35 sec. for full frame

Table 4. Approximate Readout Time for the Frame-Transfer CCD Array

Interline

In this section, a simple 6 × 3 pixel interline CCD is used to demonstrate how charge is shifted and digitized. As described below, two different types of readout, overlapped and non-overlapped can occur. In overlapped operation, each exposure begins while the readout of the previous one is still in progress. In non-overlapped operation (selected automatically if the exposure time is shorter than the readout time) each readout goes to completion before the next exposure begins.

Overlapped Operation Exposure and Readout

Figure 30 illustrates exposure and readout when operating in the overlapped mode. Figure 30 contains four parts, each depicting a later stage in the exposure-readout cycle. Eight columns of cells are shown. Columns 1, 3, and 5 contain imaging cells while columns 2, 4, and 6 contain storage cells. The readout register is shown above the array.

Part 1 of the figure shows the array early in the exposure. The imaging cells contain charge proportional to the amount of light integrated on each of them. The storage cells are empty because no charge has been transferred to them. The arrows between adjacent imaging and storage cells indicate the direction the charge will be shifted when the transfer occurs.

Part 2 of Figure 30 shows the situation early in the readout. The charge in the imaging cells has been transferred to the adjacent storage cells and up-shifting to the readout register has started. Note that a new exposure begins immediately.

Part 3 of Figure 30 shows the transfer to the output node. The lowermost cell in each column is shown empty. Each row of charges is moved in turn into the readout register, and from there to the output node and off of the array for further processing. The process continues until all charges have been completely transferred out of the array. The imaging cells continue accumulating charge throughout the readout process. Integrating in this way while the readout takes place achieves the maximum possible time efficiency.

Part 4 of Figure 30 illustrates the situation at the end of the readout. The storage cells and readout register are empty, but the ongoing accumulation of charge in the imaging cells continues until the end of the programmed exposure.

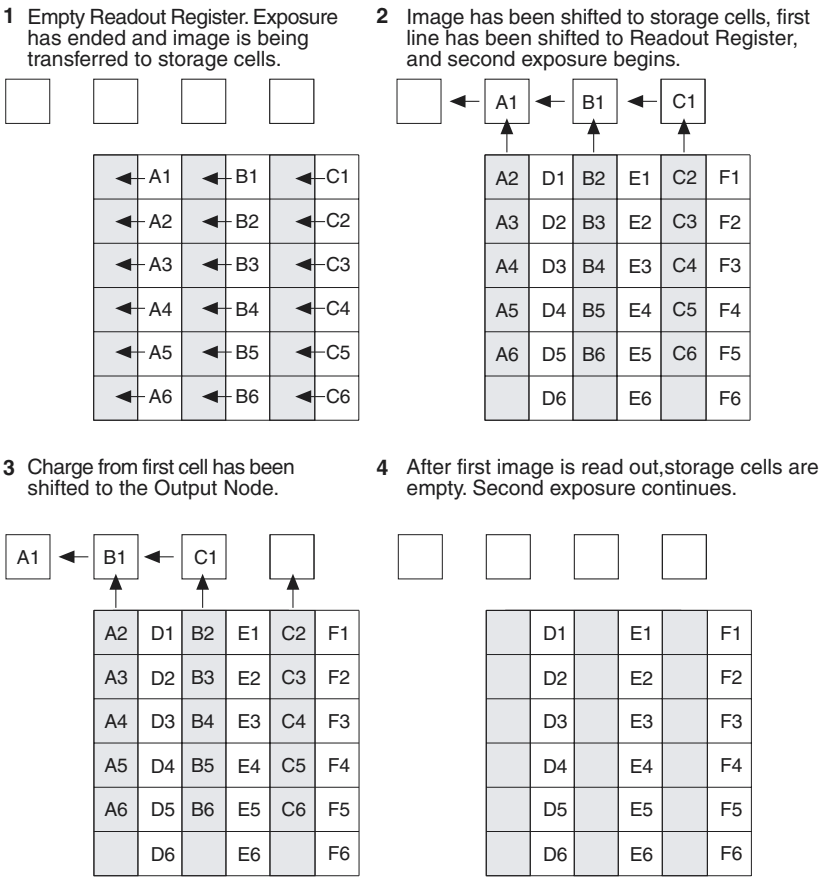

1 Empty Readout Register. Exposure has ended and image is being transferred to storage cells.
2 Image has been shifted to storage cells, first line has been shifted to Readout Register, and second exposure begins.
3 Charge from first cell has been shifted to the Output Node.
4 After first image is read out,storage cells are empty. Second exposure continues.

Figure 30. Overlapped Mode Exposure and Readout

Non-Overlapped Operation Exposure and Readout

Figure 31 illustrates exposure and readout when operating in the non-overlapped mode. Non-overlapped operation occurs automatically any time the exposure time is shorter than the readout time. Figure 31 contains four parts, each depicting a later stage in the exposure-readout cycle.

Part 1 of the figure shows the array early in the exposure. The imaging cells contain charge proportional to the amount of light integrated on each of them. The storage cells are empty because no charge has been transferred to them. The arrows between adjacent imaging and storage cells indicate the direction the charge will be shifted when the transfer occurs.

Part 2 of Figure 31 shows the situation early in the readout cycle. The charge in the imaging cells has been transferred to the adjacent storage cells and up-shifting to the readout register has started. Note that a second exposure doesn't begin while the readout is in progress.

Part 3 of Figure 31 shows the transfer to the output node. The lowermost cell in each column is shown empty. Each row of charges is moved in turn into the readout register, and from there to the output node and off of the array for further processing. The process continues until all charges have been completely transferred out of the array. The imaging cells are electronically switched off and do not accumulate any charge as the readout takes place. Because this scheme is less time efficient than that used in the overlapped mode, the frame rate may be lower in non-overlapped operation than it is in overlapped operation with the some exposure time settings.

Part 4 of Figure 31 illustrates the situation at the end of the readout. Both the imaging and storage cells are empty. In Free Run operation, the imaging cells will be switched back on immediately, allowing charge accumulation to begin. In Ext Sync operation with no PreOpen, they are not switched back on until after the External Sync pulse is detected.

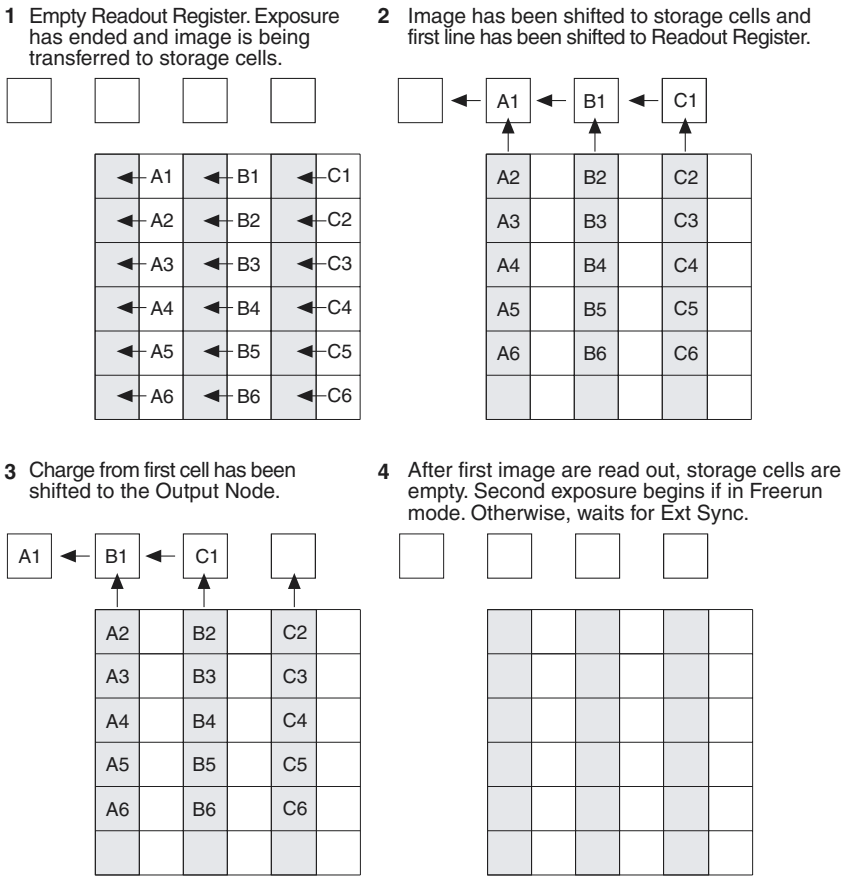

1 Empty Readout Register. Exposure has ended and image is being transferred to storage cells.
2 Image has been shifted to storage cells and first line has been shifted to Readout Register.
3 Charge from first cell has been shifted to the Output Node.
4 After first image are read out, storage cells are empty. Second exposure begins if in Freerun mode. Otherwise, waits for Ext Sync.
A1 B1 C1
A2 B2 C2
A3 B3 C3
A4 B4 C4
A5 B5 C5
A6 B6 C6

Figure 31. Non-Overlapped Mode Exposure and Readout

A subsection of the CCD can be read out at full resolution, sometimes increasing the readout rate while retaining the highest resolution in the region of interest (ROI).

Readout Rate for Interline

Below are the equations that determine the rate at which the CCD is read out. Tables of values for CCDs supported at the time of the printing of this manual also appear below.

Assuming the shutter selection is **None**, the time needed to take a full frame at full resolution in non-overlapped timing mode is:

$$t_R + t_{exp} \tag{1}$$

where

t_R is the CCD readout time,
t_{exp} is the exposure time, and

The readout time is approximately given by:

$$t_R = [N_x \cdot N_y \cdot (t_{sr} + t_v)] + (N_x \cdot t_i) \tag{2}$$

where

N_x is the smaller dimension of the CCD
N_y is the larger dimension of the CCD.
t_{sr} is the time needed to shift one pixel out of the shift register
t_v is the time needed to digitize a pixel
t_i is the time needed to shift one line into the shift register

CCD Array	1 MHz Readout	5 MHz Readout
MicroMAX:782Y Sony ICX075 782 x 582	0.5 sec. for full frame	N/A
MicroMAX:782YHS Sony ICX075 782 x 582	N/A	0.11 sec. for full frame
MicroMAX:1300Y Sony ICX061 1300x1030	1.43 sec. for full frame	N/A
MicroMAX:1300YHS Sony ICX061 1300x1030	N/A	0.33 sec. for full frame

Table 5. Approximate Readout Time for the Interline CCD Arrays

The readout rate in frames per second for the PI 1300 × 1030 interline array running at 1 MHz is shown in Table 6.

	Region of Interest Size			
Binning	**1300 × 1030**	**400 × 400**	**200 × 200**	**100 × 100**
1 × 1	0.7	2.6	5.4	9
2 x 2	1.9	5.4	9	14
3 × 3	3.2	7.5	12	17
4 × 4	4.3	9	14	19

Table 6. Readout Rates for PI 1300 × 1030 Array at 1 MHz

A subsection of the CCD can be read out at full resolution, sometimes increasing the readout rate while retaining the highest resolution in the region of interest (ROI).

Binning

On-Chip Binning

Binning is the process of adding the data from adjacent pixels together to form a single pixel (sometimes called a super-pixel), and it can be accomplished in either hardware or software. Rectangular groups of pixels of any size may be binned together, subject to some hardware and software limitations.

Hardware binning is performed *before* the signal is read out by the preamplifier. For signal levels that are readout noise limited this method improves S/N ratio linearly with the number of pixels grouped together. For signals large enough to

render the camera photon shot noise limited, the S/N ratio improvement is roughly proportional to the square-root of the number of pixels binned.

Figure 32 shows an example of 2 × 2 binning for a full frame CCD array. Each pixel of the image displayed by the software represents 4 pixels of the array. Rectangular bins of any size are possible.

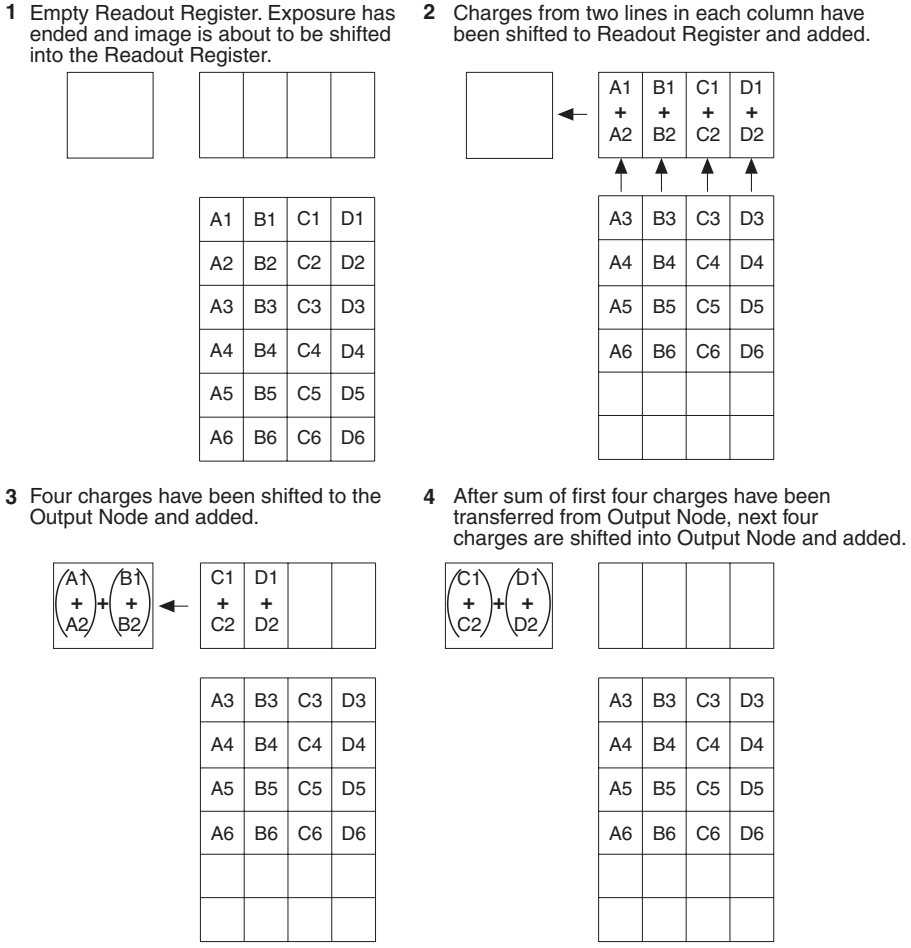

1 Empty Readout Register. Exposure has ended and image is about to be shifted into the Readout Register.
2 Charges from two lines in each column have been shifted to Readout Register and added.
3 Four charges have been shifted to the Output Node and added.
4 After sum of first four charges have been transferred from Output Node, next four charges are shifted into Output Node and added.
A1 B1 C1 D1
A2 B2 C2 D2
A3 B3 C3 D3
A4 B4 C4 D4
A5 B5 C5 D5
A6 B6 C6 D6

Figure 32. 2 × 2 Binning for Full Frame CCD

Binning also reduces readout time and the burden on computer memory, but at the expense of resolution. Since shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and “blooming”, or spilling of charge back into the image area.

The readout rate for n × n binning is approximated using a more general version of the full resolution equation. The modified equation is:

$$t_R = \left[N_x \cdot N_y \cdot \left(\frac{t_{sr}}{n} + \frac{t_v}{n^2} \right) \right] + \left(N_x \cdot t_i \right) \qquad (3)$$

On-Chip Binning for Interline

Binning is the process of adding the data from adjacent cells together), and it can be accomplished in either hardware or software. Rectangular groups of cells of any size may be binned together, subject to some hardware and software limitations.

Hardware binning is performed *before* the signal is read out by the preamplifier. For signal levels that are readout noise limited this method improves S/N ratio linearly with the number of cells grouped together. For signals large enough to render the camera photon shot noise limited, the S/N ratio improvement is roughly proportional to the square-root of the number of pixels binned.

Figure 33 shows an example of 2 × 2 binning. Each cell of the image displayed by the software represents 4 cells of the CCD array. Rectangular bins of any size are possible.

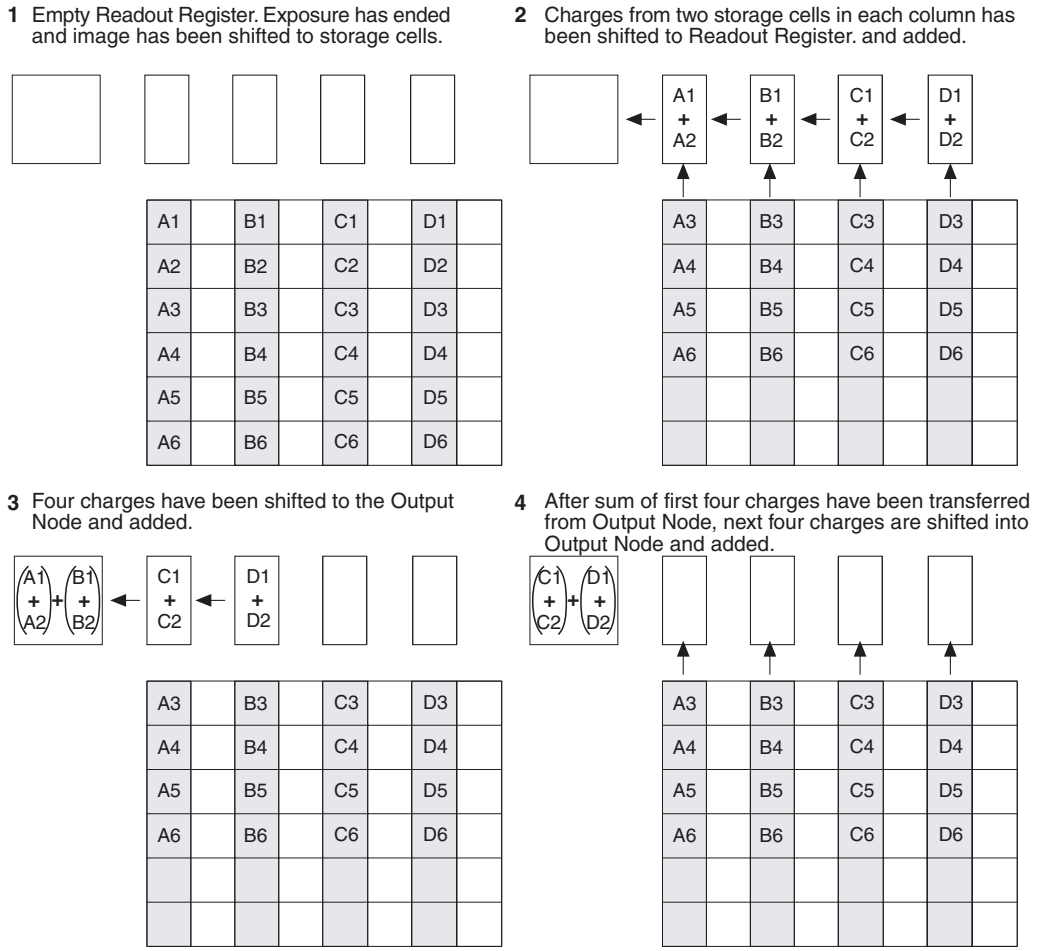

1 Empty Readout Register. Exposure has ended and image has been shifted to storage cells.
2 Charges from two storage cells in each column has been shifted to Readout Register. and added.
3 Four charges have been shifted to the Output Node and added.
4 After sum of first four charges have been transferred from Output Node, next four charges are shifted into Output Node and added.
A1 + A2
B1 + B2
C1 + C2
D1 + D2

Figure 33. 2 × 2 Binning for Interline CCD

Software Binning

One limitation of hardware binning is that the shift register pixels and the output node are typically only 2-3 times the size of imaging pixels as shown in Table 7. Consequently, if the total charge binned together exceeds the capacity of the shift register or output node, the data will be corrupted.

This restriction strongly limits the number of pixels that may be binned in cases where there is a small signal superimposed on a large background, such as signals with a large fluorescence. Ideally, one would like to bin many pixels to increase the S/N ratio of the weak peaks but this cannot be done because the fluorescence would quickly saturate the CCD.

CCD Array	Imaging/Storage Cells Well Capacity	Readout Register Well Capacity	Output Node Well Capacity
EEV CCD-37 512 x 512	100 x 10^3 electrons	200 x 10^3 electrons	400 x 10^3 electrons
PID 582 x 782	18 x 10^3 electrons	40 x 10^3 electrons	40 x 10^3 electrons
PID 1030 x 1300	34 x 10^3 electrons	34 x 10^3 electrons	65 x 10^3 electrons

Table 7. Well Capacity for some CCD Arrays

The solution is to perform the binning in software. Limited hardware binning may be used when reading out the CCD. Additional binning is accomplished in software, producing a result that represents many more photons than was possible using hardware binning.

Software averaging can improve the S/N ratio by as much as the square root of the number of scans. Unfortunately, with a high number of scans, i.e., above 100, camera 1/f noise may reduce the actual S/N ratio to slightly below this theoretical value. Also, if the light source used is photon-flicker limited rather than photon shot-noise limited, this theoretical signal improvement cannot be fully realized. Again, background subtraction from the raw data is necessary.

This technique is also useful in high light level experiments, where the camera is again photon shot-noise limited. Summing multiple pixels in software corresponds to collecting more photons, and results in a better S/N ratio in the measurement.

Digitization

During readout, an analog signal representing the charge of each pixel (or binned group of pixels) is digitized. The number of bits per pixel is based on both the hardware and the settings programmed into the camera through the software. The MicroMAX can contain up to two A/D converters with different readout rates selectable through software.

Dual A/D Converters

There is provision in the MicroMAX Camera for two A/D converters to provide optimum signal-to-noise ratios at both readout speeds. Because the readout noise of CCD arrays increases with the readout rate, it is sometimes necessary to trade off readout speed for high dynamic range. Although slowing the readout speed of a high-speed A/D converter gives some improvement in signal-to-noise ratio, a fast A/D converter will

always be nosier than one designed for optimum noise performance. The MicroMAX camera can be provided with two analog converters, one optimized for high speed, the other for high precision, as a solution to this problem. For the most common system configurations, there will be a 1 MHz converter for the fastest possible data collection, and a 100 kHz converter for use where noise performance is the paramount concern. Switching between the channels is completely under software control for total experiment automation.

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Chapter 7

MicroMAX DIF Camera (Double Image Feature)

Introduction

This Appendix describes operation of the MicroMAX DIF system. Both the Controller and a MicroMAX Interline camera must have factory modifications installed for DIF operation. In addition to the internal changes and installation of a back panel switch, a camera modified for DIF operation would ordinarily include a mechanical shutter. Execution of the DIF functions is done via the WinView/32 software (v2.2 or higher), which, when controlling a DIF system, provides three timing modes unique to DIF systems.

Basically, a DIF system is one that has been factory modified to allow images to be taken in pairs with very short exposure times (as small as 1 µs). This capability makes it ideal for use in experiments where the goal is to obtain two fast successive images for the purpose of characterizing a time-differentiated laser-strobed process. LIF and velocity measurements are specific measurements that can be easily performed using the DIF system.

The ability of the interline chip to quickly transfer an image under the masked columns and hold it there makes this method of acquiring images possible. As soon as the first image is acquired, it is shifted under the masked area and held. The second exposure begins and is continuously held in the photodiode region until the mechanical shutter closes. Light entering the camera while waiting for the shutter to close is small compared to that captured during the strobed event and has little effect on the acquired data.

In addition to the Free Run mode, which allows single image acquisitions, three DIF timing modes, IEC (Internal Exposure Control), EEC (External Exposure Control) and ESABI (Electronic Shutter Active Between Images) are provided. Each works basically as follows.

IEC: Allows two *successive* fast images *of equal duration* to be acquired, with the second image acquisition taking place immediately after the first. Acquisition is initiated by applying a single externally derived trigger to the controller's **Ext. Sync** connector.

EEC: Allows two *successive* fast images *of differing duration* to be acquired, with the second image acquisition taking place immediately after the first. Acquisition is initiated by applying a single externally derived trigger to the controller's **Ext. Sync** connector, the same as in IEC operation.

ESABI: Allows two fast images *of equal duration* to be acquired. Unlike the IEC and EEC modes, in the ESABI mode, two pulses are applied to the **Ext. Sync.** connector. Each initiates a separate acquisition, allowing the user to set the time between acquisitions by externally adjusting the time between the two applied pulses.

When the data is saved, both images are saved in a single *.spe file. The header is followed by frame 1 and then immediately afterwards by frame 2. This system makes it convenient to later load the images from the file for post-processing analysis.

Notes:
A MicroMAX DIF camera has a switch on its back panel that is not present in standard MicroMAX cameras. This switch must be set to the **ACTIVE** position for operation in the **ESABI** timing mode. At all other times it must be set to **INACTIVE**.

The Readout Mode set on the Controller/Camera Hardware Setup page ***must*** be set to **Full Frame** for DIF operation. Do ***not*** select the **Interline** Readout mode, even though, intuitively, **Interline** may seem to be the logical choice.

In the IEC, EEC or ESABI timing mode, set the **Number of Images** to 2 and **Accumulations** to 1.

On the Setup Hardware **Cleans/Skips** tab page, click the **Load Factory Values** button. This step is necessary for proper operation of the interline camera.

Timing Modes

The timing mode selections provided on the Acquisition Experiment Setup **Timing** page are different from those in standard systems. The provided timing modes are:

FREERUN (single shot)
IEC: Internal Exposure Control (two shot)
EEC: External Exposure Control (two shot)
ESABI: Electronic Shutter Active Between Images (two shot)

A discussion of each mode follows.

Free Run

The Free Run mode allows the user to capture single images. The exposure time is set on the Experiment Setup **Main** tab page, the same as in non-DIF systems, with the difference that the exposure time can be as short as one 1 µs (maximum exposure time is 14.3 minutes). It often proves convenient to simply disable the mechanical shutter open in Free Run operation. The shutter requires ~8 ms to open and 8 ms to close. The camera waits until the shutter is completely open before acquiring the image, and in a typical experiment, the second image acquisition will be over long before the shutter closes. Readout doesn't occur until the shutter closes.

The $\overline{\textbf{READY}}$ signal output of the controller can be used to trigger external equipment, such as the laser. As soon as the shutter is completely opened and all of the cleans have been performed, $\overline{\textbf{READY}}$ goes low to indicate that the camera is ready to capture an image. As soon as the first exposure actually begins, $\overline{\textbf{READY}}$ returns high, as shown in

Figure 34. Thus the positive going edge of the **$\overline{\text{READY}}$** output marks the start of the first exposure. In Free Run operation, the time that **$\overline{\text{READY}}$** remains low will typically be in the range of 400 to 600 ns.

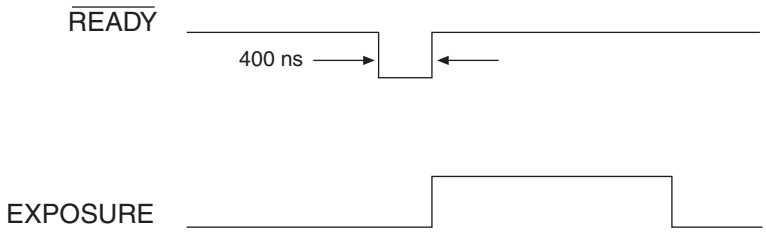

Figure 34. Free Run Mode Timing Diagram

Example: Figure 35 shows an experiment where the rising edge of the **$\overline{\text{READY}}$** signal is used to trigger a DG-535 Delay Generator, which provides the required delay and triggers a laser source, Q switch, or other device.

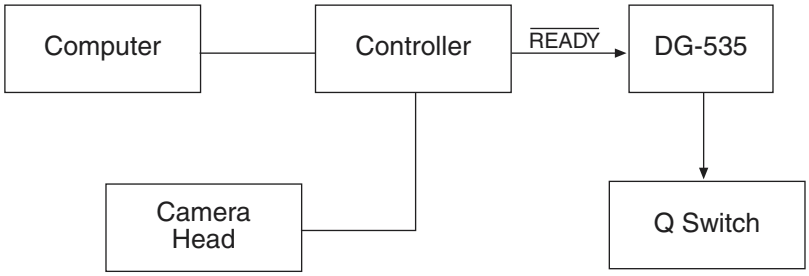

Figure 35. Setup using $\overline{\text{READY}}$ to Trigger an Event

Figure 36 illustrates the timing for a typical experiment like that shown in Figure 35.

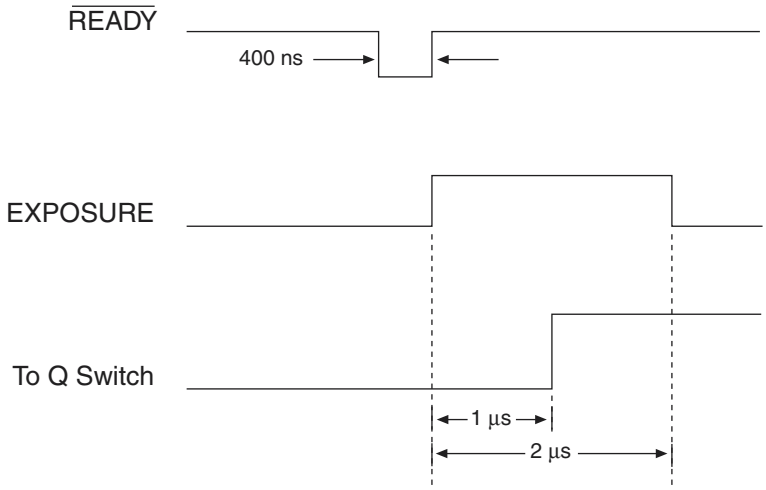

Figure 36. Timing for Experiment Setup shown in Figure 35

Summary of Free Run Timing mode

- Allows user to capture single images.
- Requires that the switch on the back of the DIF camera be set to **INACTIVE**.
- Uses Exposure Time set via software Experiment Setup.
- Exposure time range is 1 µs < Exp. Time < 14.3 minutes
- Exposure does not occur until the mechanical shutter is completely open and readout does not begin until the mechanical shutter is completely closed.
- The mechanical shutter may, however, be disabled open.
- The **$\overline{\text{READY}}$** signal on the back of the controller may be used as a trigger to other external hardware. **$\overline{\text{READY}}$** goes low when the system is ready to capture an image, then is reset high once exposure begins. In the **FREERUN** timing mode, this will be a short (400 ns to 600 ns) TTL 0 pulse.

IEC (Internal Exposure Control)

In this mode, a single external trigger applied to **Ext Sync** initiates two successive image acquisitions of equal duration. The Exposure Time is set in software (Experiment Setup **Main** tab page and elsewhere) the same as in a standard system and can be as short as 1 µs. On initiating the acquisition (**ACQ** button or **Acquire** on the Acquisition menu), the initialization routine runs and the shutter opens. When the shutter is completely open, **$\overline{\text{READY}}$** drops low and remains in that state until an external trigger is applied to **Ext Sync**. Continuous cleaning takes place until the trigger is applied. When the trigger is sensed, the first exposure begins and the first image is captured (shifted under the masked columns and held there). The exposure for capture of the second image begins. This sequence is illustrated in Figure 37.

If an external trigger is applied before **$\overline{\text{READY}}$** goes low, it will be ignored. Thus the trigger source could be running continuously at some repetition rate (as long as that rep rate is fairly slow), but capture wouldn't occur until **$\overline{\text{READY}}$** goes low. once that trigger comes in, it begins exposure of the first image. The exposure time is that set on the Experiment Setup **Main** tab page. For example, if the exposure time is set to 5 µs, the first image will be 5 µs. After an additional 5 µs (second exposure), the shutter will begin to close. Even though the shutter takes ~8 ms to close, the presumption is that the strobe will be timed to occur during the 5 µs second exposure time. It would also be possible to strobe and capture while the shutter is in the act of closing. However, that would generally not be advisable because it would introduce non-linearity effects from the closing shutter. It is better to have capture occur during the time allotted for it. Once the shutter is closed, the readout begins. The first image captured is the first one read out.

Example 1: An external trigger initiates the imaging process. **$\overline{\text{READY}}$** goes low when the system is ready. Once **$\overline{\text{READY}}$** is low, an external trigger applied to **Ext Sync** initiates the double image capture. Figure 37 illustrates the timing for a typical IEC experiment with an exposure time of 5 µs.

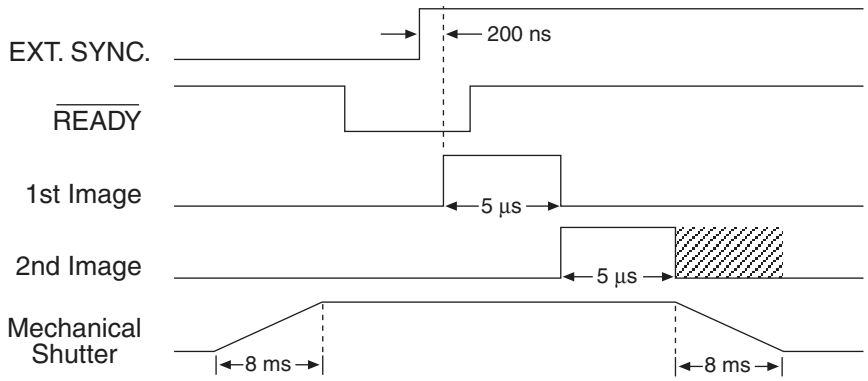

Figure 37. Timing Diagram for Typical IEC Measurement

Figure 38 illustrates the interconnections that might be used for such an experiment with two lasers. Figure 39 shows the timing for the two-laser experiment.

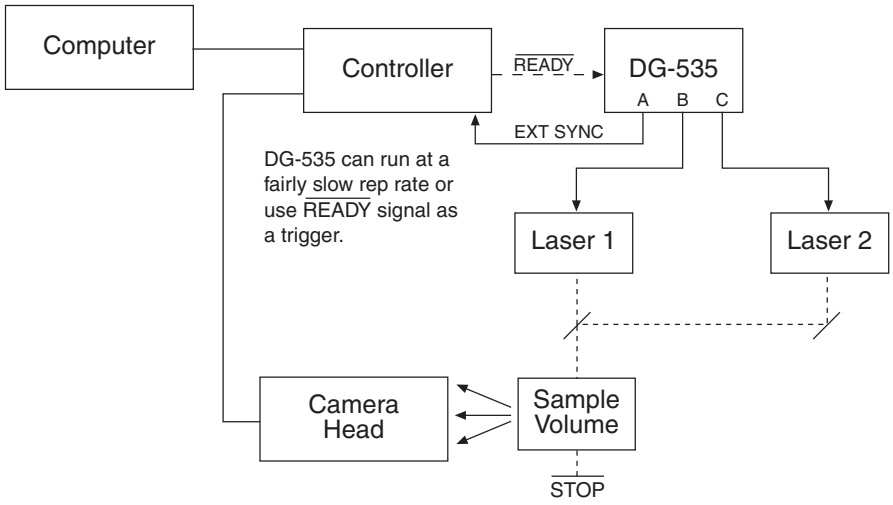

Figure 38. Setup for IEC Experiment with Two Lasers

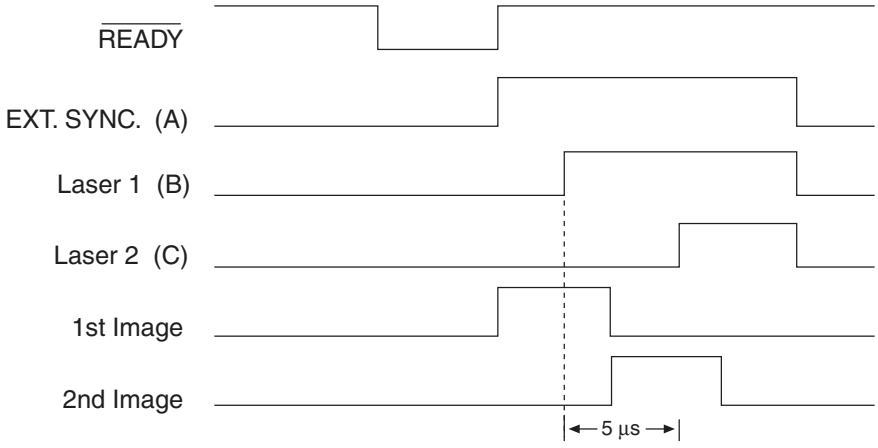

Figure 39. Timing Diagram for IEC Experiment with Two Lasers

Example 2: As shown in Figure 40, the **$\overline{\text{READY}}$** signal from the controller can be used to trigger the controller by connecting it back into the **EXT SYNC** connector. At the same time, it can be used to trigger a DG-535.

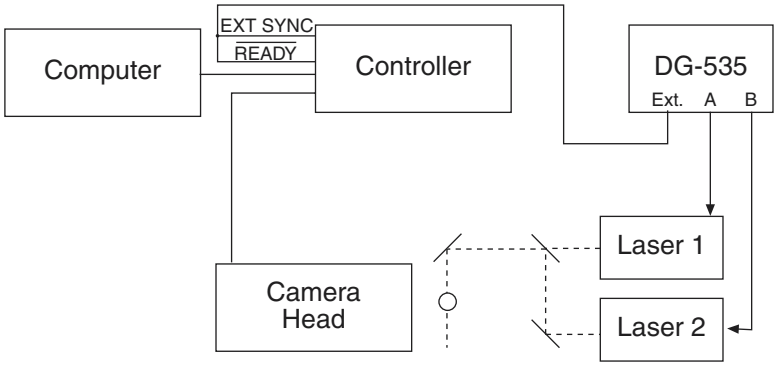

Figure 40. Another Hardware Setup for an IEC Measurement

Note: This setup will ***not*** work in the **EEC** mode or the **ESABI** mode.

Summary of IEC Timing mode

- Gives the user the ability to capture two images before readout.
- Requires that the switch on the back of the DIF camera be set to **INACTIVE**.
- The Exposure Time set in software on the Experiment Setup **Main** tab page becomes the exposure time of the first image and also the wait before closing the mechanical shutter.
- An external trigger is required to initiate the imaging process. The **$\overline{\text{READY}}$** goes low when the system is ready. Once **$\overline{\text{READY}}$** is low, an external trigger applied to the **EXT SYNC** connector initiates the double image capture.

EEC (External Exposure Control)

Gives the user the ability to capture two images before readout with a different exposure time for each. EEC uses the external trigger to control the exposure time of the first image and the exposure time set in software to control the exposure time of the second image. When the external trigger applied to **Ext Sync** is detected, the first exposure begins. The end of the trigger marks the end of the first image and the start of the second. After an interval equal to the exposure time set on the Experiment Setup **Main** page, the shutter closes. As in the IEC mode, the system is receptive to an applied trigger when **$\overline{\text{READY}}$** goes low. Note that the shutter can be disabled open. With the shutter disabled open, if reading out a full array, the second exposure time would actually last ~1.4 s. If reading out a single strip, the readout time (and hence the second exposure) would be much shorter, on the order of a few hundred microseconds. Generally though, the experiment timing would be set up so that the second strobed event would occur during the second image time as set by the Exposure Time parameter on the Experiment Setup **Main** page.

Example: The exposure time for the first image is controlled with the signal applied to the **EXT. SYNC** connector. The exposure time for the second image is the exposure time set in software under Experiment Setup. An external trigger

supplied by the user is required to initiate the imaging process and control the first image exposure time. The controller **READY** signal goes low when the camera is ready to begin imaging. Figure 41 illustrates an EEC timing example.

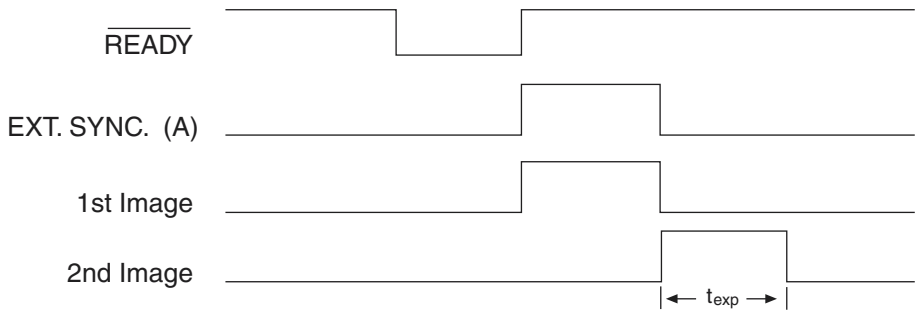

Figure 41. EEC Timing Example with Exposure Time in Software Set to t_{exp}

Summary of EEC Timing mode

- Enables double image capture under external control.
- Requires that the switch on the back of the DIF camera be set to **INACTIVE**.
- The width of the pulse applied to **Ext Sync** sets the exposure time of the first image. The Exposure Time set in software on the Experiment Setup **Main** tab page sets the second image time, at the end of which the shutter begins to close.
- An external trigger is required to initiate the imaging process. The **READY** goes low when the system is ready. Once **READY** is low, an external trigger applied to the **Ext Sync** connector initiates the double image capture.

ESABI (Electronic Shutter Active Between Images)

The last timing mode, ESABI, allows separation time between the two images. This mode gives the user the ability to capture two images and use the interline chip's electronic shutter feature between images so that no signal is integrated in the time between. The exposure time for both images is the same but they can be separated in time. Each time the camera is ready to receive a trigger, **READY** goes low. Thus **READY** goes low twice during each ESABI cycle and the controller can be triggered once by a sync pulse applied to **Ext Sync** each time. Thus two sync pulses are required, one for each image, during each double capture. The programmed Exposure Time as set on the Experiment Setup **Main** tab page sets the first image time and the time after the start of the second image time when the shutter begins to close. Figure 42 illustrates ESABI mode timing.

Note that charge produced by light impinging on the photosensors during the interval between the two images is discarded and does not affect the second image. The time between the first and second image can be as long as required according to the experimental requirements. This can be particularly useful in fluorescence measurements. By doing captures with different intervals between the two images, the fluorescence decay characteristics can be easily measured.

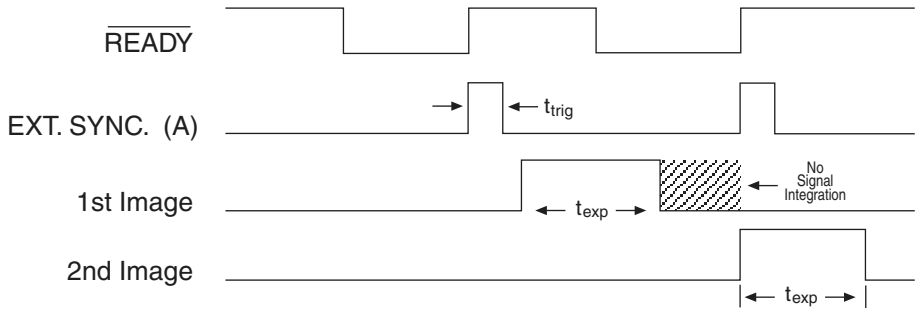

Figure 42. ESABI Timing Example: Image Exposure time = t_{exp} set in software

Note: The input trigger pulse, t_{trig}, must be shorter than the exposure time t_{exp}. Otherwise the second image will occur immediately after the first.

Summary of ESABI Timing mode

- The exposure time selected in Experiment Setup sets the exposure time of both the first and second image.
- Requires that the switch on the back of the DIF camera be set to **ACTIVE**.
- An externally derived trigger edge applied to **Ext Sync** is required to begin each image exposure period.
- **$\overline{\text{READY}}$** goes low when the system is ready to capture ***each*** image.

Tips and Tricks

Lab Illumination

In DIF measurements, it is necessary to remain mindful of the possibility of laboratory light affecting the images. Because the first image can be timed with precision, laboratory light that reaches the camera would generally not be a problem in the first image, particularly if the capture time is short (few microseconds). The second image, on the other hand, is much more susceptible to degradation from laboratory illumination because, even though the second image time may be set to just a few microseconds, the time to close the shutter, ~8 ms, must be added to that value. Light impinging on the photosensors during that time will be integrated with the second image. Unless the experiment is arranged so that background light can't reach the camera, or unless the signal is quite bright, the possibility of the second image becoming degraded must be considered. Where this is source of degradation is a problem, the solution may be to sharply reduce the laboratory illumination. It should be noted though, that the signal from many strobed measurements will be sufficiently bright to allow normal laboratory illumination to be maintained.

Background Subtraction

In any of the double imaging modes, a good idea would be to block both of your light sources and go ahead and take two images in the same DIF mode and with the same settings as will be used for the real measurements. That result will be two background images that can later be subtracted from the experimental data images.

Background subtraction allows you to automatically subtract any constant background in your signal. This includes both constant offsets caused by the amplifier system in the

controller as well as time-dependent (but constant for a fixed integration time) buildup of dark charge. The background subtract equation is:

(Raw image data – Background) = Corrected image data.

When background and flatfield operations are both performed, background subtraction is always performed first.

Flatfield Correction

Flatfield correction allows the user to divide out small nonuniformities in gain from pixel to pixel. Flatfield correction is done before the images are saved to RAM or disk. Directions for doing Flatfield correction are provided in the WinView/32 software manual.

Mask Bleed-Through Correction

As described previously, the first image is stored under the mask while the second image is being acquired. Although the mask is basically opaque (light attenuation is on the order of 4000:1), a small amount of illumination does get through and could influence some measurements. One solution would be to establish a correction file by taking the first image with the light source dark, and the second image with the light source on. Any bleed through the mask during the second image will appear in the first image. This data could then be stored and used later to correct “real” first images in a post-processing math operation.

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Chapter 8
TTL Control

Introduction

This connector provides 8 TTL lines in, 8 TTL lines out and an input control line. Figure 43 illustrates the connector and Table 9 lists the signal/pin assignments.

Princeton Instruments WinView/32 software packages incorporate WinX32 Automation, a programming language that can be used to automate performing a variety of data acquisition and data processing functions, including use of the TTL IN/OUT functions. WinX32 Automation can be implemented in programs written in Vision Basic or Visual C++. See the WinX32 documentation for more detailed information.

TTL In

The user controls the 8 TTL Input lines, setting them high (+5 V; TTL 1) or low (0 V; TTL 0). When the lines are read, the combination of highs and lows read defines a decimal number which the computer can use to make a decision and initiate actions as specified in the user's program. If a TTL IN line is low, its numeric value is 0. If a TTL IN line is high, its numeric value is as follows.

TTL IN 1	1
TTL IN 2	2
TTL IN 3	4
TTL IN 4	8
TTL IN 5	16
TTL IN 6	32
TTL IN 7	64
TTL IN 8	128

This coding allows any decimal value from 0 to 255 to be defined. Thus as many as 256 different sets of conditions can be specified, at the user's discretion, using the TTL IN lines. For example, to define the number three, the user would simply set the lines TTL IN 1 and TTL IN 2 both high (+5 V). Because unused lines default to TTL high, it will be necessary to connect TTL logic low (0) to them as shown below.

TTL IN 1	high (1)
TTL IN 2	high (2)
TTL IN 3	low (0)
TTL IN 4	low (0)
TTL IN 5	low (0)
TTL IN 6	low (0)
TTL IN 7	low (0)

Table 8 illustrates this coding for decimal values 0 through 7. Obviously this table could easily be extended to show the coding for values all the way to 255.

Decimal Equiv.	TTL IN/OUT 8 1= dec 128	TTL IN/OUT 7 1=dec 64	TTL IN/OUT 6 1=dec 32	TTL IN/OUT 5 1=dec 16	TTL IN/OUT 4 1=dec 8	TTL IN/OUT 3 1=dec 4	TTL IN/OUT 2 1=dec 2	TTL IN/OUT 1 1=dec 1
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1
2	0	0	0	0	0	0	1	0
3	0	0	0	0	0	0	1	1
4	0	0	0	0	0	1	0	0
5	0	0	0	0	0	1	0	1
6	0	0	0	0	0	1	1	0
7	0	0	0	0	0	1	1	1

Table 8. Bit Values with Decimal Equivalents:
1 = High,
0 = Low

Buffered vs. Latched Inputs

In controlling the TTL IN lines, users also have the choice of two input-line states, *buffered* or *latched*. In the buffered state, the line levels must remain at the intended levels until they are read. With reference to the preceding example, the high level at TTL IN 1 and TTL IN 2 would have to be maintained until the lines are read. In the latched state, the applied levels continue to be available until read, even if they should change at the TTL IN/OUT connector.

This control is accomplished using the EN/CLK TTL input (pin 6). If EN/CLK is open or high, *buffered* operation is established and the levels reported to the macro will be those in effect when the READ is made. With reference to our example, if pin 6 were left unconnected or a TTL high applied, TTL IN 1 and TTL IN 2 would have to be held high until read. If, on the other hand, EN/CLK were made to go low while TTL IN 1 and TTL IN 2 were high, those values would be *latched* for *as long as EN/CLK remained low*. The levels actually present at TTL IN 1 and TTL IN 2 could then change without changing the value that would be read by software.

TTL Out

The state of the TTL OUT lines is set from WinView/32. Typically, a program monitoring the experiment sets one or more of the TTL Outputs. Apparatus external to the MicroMAX system interrogates the lines and, on detecting the specified logic levels, takes the action appropriate to the detected condition. The coding is the same as for the input lines. There are eight output lines, each of which can be set low (0) or high (1). The combination of states defines a decimal number as previously described for the TTL IN lines.

Pin #	Assignment	Pin #	Assignment
1	IN 1	14	IN 2
2	IN 3	15	IN 4
3	IN 5	16	IN 6
4	IN 7	17	IN 8
5	GND	18	GND
6	EN/CLK	19	Reserved
7	(future use)	20	GND
8	GND	21	OUT 2
9	OUT 1	22	OUT 4
10	OUT 3	23	OUT 6
11	OUT 5	24	OUT 8
12	OUT 7	25	GND
13	Reserved		

Table 9. TTL IN/OUT Connector Pinout

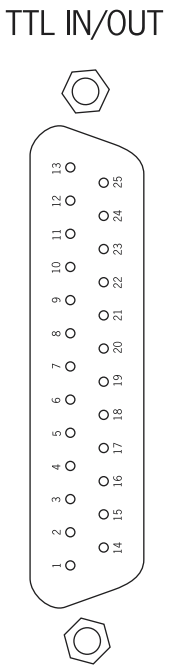


Figure 43. TTL IN/OUT Connector

TTL Diagnostics Screen

WinView/32 provides a TTL Diagnostics screen (located in WinView/32 under **Hardware Setup|Diagnostics***)* that can be used to test and analyze the TTL In/Out lines.

Note: In WinView software versions prior to 1.6, Output Lines 5, 6, 7, and 8 are shown checked in the default state, incorrectly indicating that their default state is logic 1 in the MicroMAX.

Hardware Interface

A cable will be needed to connect the TTL In/Out connector to the experiment. The design will vary widely according to each user's needs, but a standard 25-pin female type D-subminiature connector will be needed to mate with the TTL In/Out connector at the ST-133. The hardware at the other end of the cable will depend entirely on the user's requirements. If the individual connections are made using coaxial cable for maximum noise immunity (recommended), the center conductor of the coax should connect to the proper signal pin and the cable shield should connect to the nearest available ground (grounds are conveniently provided at pins 5, 8, 18 and 20). Connector hardware and cables of many different types are widely available and can often be obtained locally, such as at a nearby Radio Shack store. A list of possibly useful items follows. Note that, although the items listed may be appropriate in many situations, they might not meet your specific needs.

- 25-pin female type D-subminiature solder type connector (Radio Shack part no 276-1548B).
- RG/58U coaxial cable.

- Shielded Metalized hood (Radio Shack part no 276-1536A).
- BNC connector(s) type UG-88 Male BNC connector (Radio Shack part no 278-103).

Example

Suppose you needed to build a cable to monitor the line TTL OUT 1. One approach would be to build a cable assembly as described in the following paragraphs. This procedure could easily be adapted to other situations.

- Begin with a 25-pin female type D-subminiature solder type connector (Radio Shack part no 276-1548B). This connector has 25 solder points open on the back.
- Referring to Figure 43, note that pin 8 = GND and pin 9 = TTL OUT 1.
- Using coaxial cable type RG/58U (6 feet length), strip out the end and solder the outer sheath to pin 8 (GND) and the inner line to pin 9 (TTL OUT 1). Then apply shielding to the lines to insulate them.
- Mount the connector in a Shielded Metalized hood (Radio Shack part no 276-1536A).
- Build up the cable (you can use electrical tape) to where the strain relief clamp holds.
- Connect a BNC connector (UG-88 Male BNC connector) to the free end of the cable following the instructions supplied by Radio Shack on the box (Radio Shack part no 278-103).
- To use this cable, connect the DB-25 to the TTL IN/OUT connector on the back of the Controller.
- To check the cable, start WinView/32 and open the TTL Diagnostics screen (located in WinView under **Hardware Setup|Diagnostics**). Click the **Write** radio button. Then click the **Output Line 1** box. Next click the **OK** button to actually set TTL OUT 1 high. Once you set the voltage, it stays until you send a new command.
- Measure the voltage at the BNC connector with a standard voltmeter (red on the central pin, black on the surrounding shielding). Before clicking **OK** at the TTL Diagnostics screen you should read 0 V. After clicking **OK** you should read +5 V.

Note that adding a second length of coaxial cable and another BNC connector would be straightforward. However, as you increase the number of lines to be monitored, it becomes more convenient to consider using a multiple conductor shielded cable rather than individual coaxial cables.

Chapter 9
System Component Descriptions

MicroMAX Camera

CCD Array: MicroMAX offers a choice of CCD technologies to improve quantum efficiency (QE) and blue/green sensitivity. Arrays are available in full-frame, interline, and frame-transfer formats. Thinned, back- illuminated devices have a higher QE across the entire visible spectrum and far superior sensitivity in the blue/ green region than front-illuminated CCDs. The MicroMAX combines back- illumination technology with frame-transfer readout to provide high sensitivity with nonshuttered operation. Interline-transfer CCDs contain alternate columns of imaging and storage cells.

Because the charge on each image pixel never has to transfer more than one row, the transfer can be made very quickly without smearing. By attaching microlenses to an interline- transfer CCD, incident light is directed to the photosensitive areas of the sensor. As a result, lens-on-chip formats dramatically improve the QE in the blue/ green region of the spectrum while still allowing fast imaging. Since no shutter is required, high-speed gating and faster focus are possible.

CCD Chamber: The vacuum-sealed CCD chamber protects the CCD from contamination as well as insulates it from the warmer air in the camera body. The inherent low humidity prevents condensation on the cooled surface of the array. The thermal barrier provided by the vacuum isolates the window from the cooled CCD, keeps the window from cooling below the dewpoint, and thereby prevents condensation on the outside of the window.

MicroMAX cameras are normally shipped with a vacuum level of ~10 mTorr or better. Because this vacuum may deteriorate over time due to outgassing of electrical components, round head MicroMAX cameras are designed with a built-in vacuum port that can be used to restore the vacuum to its original level. Instructions for repumping the vacuum are provided in Appendix E.

Window: The camera has one window in the optical path. The high-quality optical quartz window is integral to the vacuum chamber. By having only one window, the MicroMAX camera reduces the chance of image degradation due to multiple reflections, stray light, and interference patterns that may occur with a multiple-window design.

Thermoelectric Cooler: While the CCD accumulates charge, thermal activity releases electrons, generating dark current. Cooling the CCD enhances the low-light sensitivity by reducing thermally generated charge. With forced-air assistance the MicroMAX camera's thermoelectric cooler is capable of cooling the CCD to -35°C with ±0.04°C stability at temperature lock.

Cooling is accomplished by mounting the CCD on a cold finger, which in turn is seated on a thermoelectric (Peltier-effect) cooler, and then transferring heat through the Peltier stages to the camera body where the heat is then radiated via a fins and removed by

forced air. CCD temperature is controlled and monitored by via the host computer and the ST-133 Controller.

Shutter: Rectangular head cameras are available with an internal 25 mm shutter.

The shutter drive signal is available at the Remote shutter connector on the rear of the ST-133 Controller or on the rear of the camera.

Electronics: The camera electronics enclosure contains the preamplifier and array driver board. This design keeps all signal leads to the preamplifier as short as possible and also provides complete RF shielding.

Speed of data acquisition and dynamic range is determined primarily by the A/D converter used (binning on the array is also a factor). MicroMAX cameras are available with 100 kHz (16-bit A/D), 100 kHz /1 MHz (16-bit A/D), 1 MHz (12-bit A/D), 1 MHz (16-bit A/D), or 5 MHz (12-bit A/D). The dual 16-bit digitizers give you the choice of the 100 kHz A/D for the better signal-to-noise ratio or the 1 MHz, 16-bit A/D for increased data acquisition speed.

Connectors: Power, control signals, and data are transmitted between the ST-133 and the MicroMAX camera via the 25-pin D connector located on the rear of the 1 MHz or 100kHz/1 MHz camera. For the 5 MHz camera, these are provided via the 15-pin and 40-pin connectors on the rear of the camera. The cables and connectors are keyed so that they cannot be connected incorrectly.

Lens Mount Housing: At the front of the camera is the lens mount housing, either C-mount or F-mount. The C-mount employs a standard size thread to make the connection while an F-mount uses a tongue and groove type mechanism to secure the lens or microscope adapter to the camera. The details of the housing will vary depending on the type of mount.

Note: C-mount cameras are shipped with a dust cover lens installed. Although this lens is capable of providing surprisingly good images, its throughput is low and the image quality is not as good as can be obtained with a high-quality camera lens. Users should replace the dust-cover lens with their own high-quality laboratory lens before making measurements.

CAUTION

If you have a camera with a UV scintillator coated CCD, protect it from excessive exposure to UV radiation. This radiation slowly bleaches the scintillator, reducing sensitivity.

Mounting Holes: The round head camera has four ¼″ x 20 UNC threaded holes on the camera body at 90° intervals. These holes are provided for flexibility in mounting the camera to your system optics. The rectangular head camera can be ordered with an optional tripod mount kit.

Fan: Depending on the camera, there may be an internal fan located inside or on the camera's back panel. Its purpose is:

- to remove heat from the Peltier device that cools the CCD array
- to cool the electronics.

  An internal Peltier device directly cools the cold finger on which the CCD is mounted. The heat produced by the Peltier device is then removed by the air

drawn into the camera by the internal fan and exhausted through the back panel. The fan is always in operation and air cooling of both the Peltier and the internal electronics takes place continuously. The fan is designed for low-vibration and does not adversely affect the image. For the fan to function properly, free circulation must be maintained between the rear of the camera and the laboratory atmosphere.

Shutter: In imaging applications an adapter is mounted to the detector and then the lens, either C-mount or F-mount, is mounted to the adapter. An F-mount adapter and a C-mount adapter differ not only in their lens-mounting provisions, but also in depth because the focal plane of F-mount lenses is deeper than that of C-mount lenses. Nevertheless, rectangular head cameras can be ordered with an internal 25 mm shutter and the appropriate lens mount adapter already installed.

Shutter Life: Note that shutters are mechanical devices with a finite lifetime, typically on the order of a million cycles, although some individual shutters may last a good deal longer. How long a shutter lasts in terms of experimental time will, of course, be strongly dependent on the operating parameters. High repetition rates and short exposure times will rapidly increase the number of shutter cycles and decrease the time when the shutter will have to be replaced. Possible shutter problems include complete failure, in which the shutter no longer operates at all, or the shutter may stick open or closed causing overexposed or smeared images. It may even happen that one leaf of the shutter will break and no longer actuate.

Shutter replacement is usually done at the factory. If you find that the shutter on your detector is malfunctioning, contact the factory to arrange for a shutter-replacement repair. Note that shutters are not covered by the warranty.

WARNING

Disconnecting or connecting the shutter cable to the detector while the controller is on can destroy the shutter or the shutter drive circuitry. ***Always power off the controller before adjusting the shutter cable.***

ST-133 Controller

Electronics: The Model ST-133 is a compact, high performance CCD Camera Controller for operation with Princeton Instruments cameras. Designed for high speed and high performance image acquisition, the ST-133 offers data transfer at speeds up to 5 megapixel per second, standard video output for focusing and alignment. A variety of A/D converters are available to meet different speed and resolution requirements.

In addition to containing the power supply, the controller contains the analog and digital electronics, scan control and exposure timing hardware, and controller I/O connectors, all mounted on user-accessible plug-in modules. This highly modularized design gives flexibility and allows for convenient servicing.

POWER Switch and Indicator: The power switch, located on the front panel as shown in Figure 44, interrupts both sides of the controller's AC power input. The switch's integral indicator LED lights whenever the ST-133 Controller is powered. Note that, when the power switch is actuated, there may be a few seconds delay before the indicator lights. This is normal and in no way indicative of a malfunction.

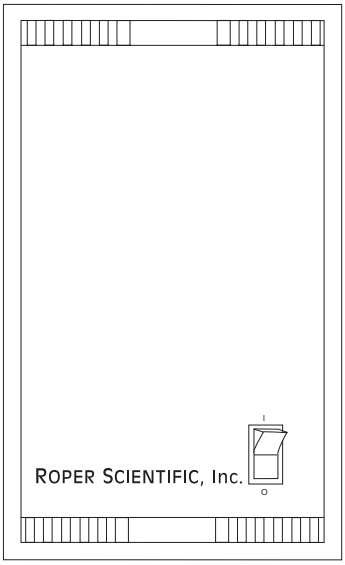


Figure 44. Controller Front Panel

Rear Panel Connectors: There are three controller board slots. Two are occupied by the plug-in cards that provide various controller functions. The third, covered with a blank panel, is reserved for future development. The left-most plug-in card is the Analog/Control module. Adjacent to it is the Interface Control module. Both modules align with top and bottom tracks and mate with a passive back-plane via a 64-pin DIN connector. For proper operation, the location of the modules should not be changed. Each board is secured by two screws that also ground each module's front panel. Removing and inserting boards is described in Chapter 10, pages 95-96.

WARNING

To minimize the risk of equipment damage, a module should ***never*** be removed or installed when the system is powered.

The **Analog/Control Module**, which should always be located in the left-most slot, provides the following functions.

- Pixel A/D conversion
- CCD scan control
- Exposure control
- Timing and synchronization of readouts
- Temperature control
- Video output control

The **Interface Control Module**, which should always be located in the center slot, provides the following functions.

- TTL in/out Programmable Interface
- High speed serial communications control

WARNING

Always turn the power off at the Controller before connecting or disconnecting any cable that interconnects the camera and controller or serious damage to the CCD may result. This damage is ***NOT*** covered by the manufacturer's warranty.

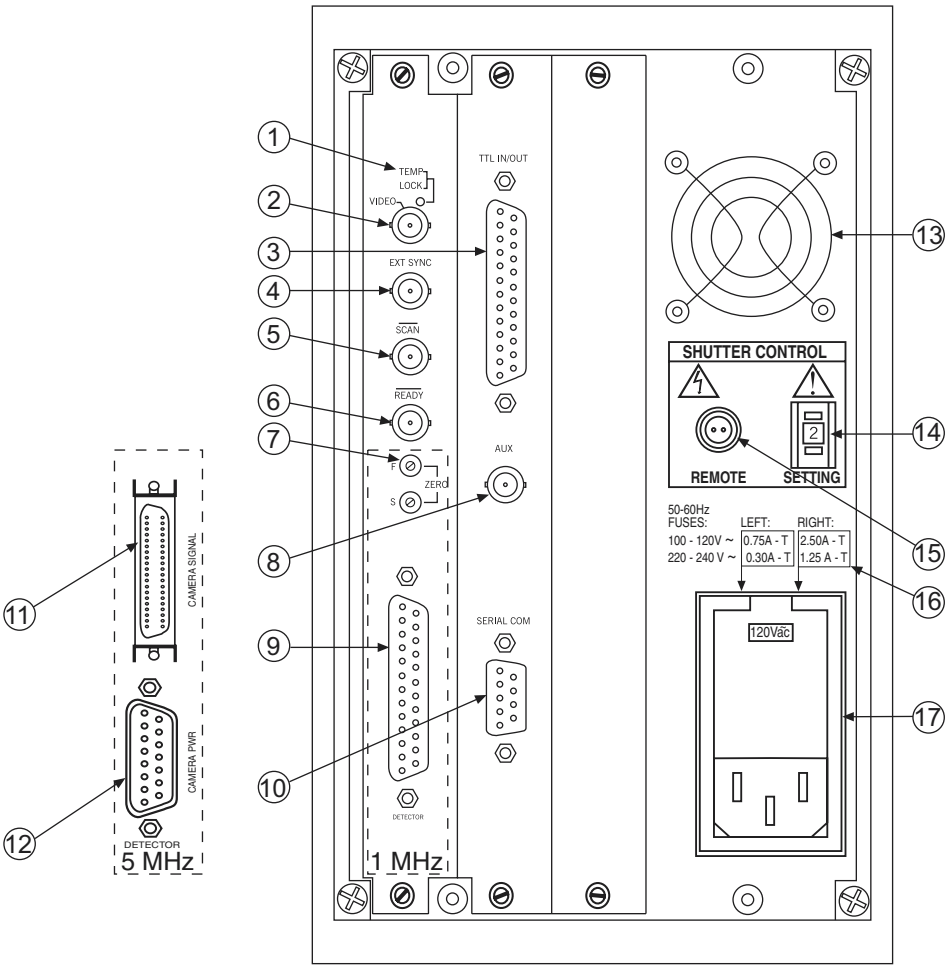


Figure 45. ST-133 Rear Panel

The descriptions of the rear panel connectors that follow are keyed to Figure 45.

#	Feature
1.	**Temperature Lock LED:** Indicates that the temperature control loop has locked and that the temperature of the CCD array will be stable to within ± 0.05°C.
2.	**Video Output:** Composite video output is provided at this connector. The amplitude is 1 V pk-pk and the source impedance is 75 Ω. Either RS-170 (EIA) or CCIR standard video can be provided and must be specified when the system is ordered. The video should be connected to the monitor via 75 Ω coaxial cable and it must be terminated into 75 Ω.
3.	**TTL In/Out:** User-programmable interface with eight input bits and eight output bits that can be written to or polled for additional control or functionality. See Chapter 8.
4.	**External Sync Input:** TTL input that has a 10 kΩ pullup resistor. Allows data acquisition and readout to be synchronized with external events. Through software, positive or negative (default) triggering can be selected.
5.	**$\overline{\text{SCAN}}$ Output** WinView/32 (ver. 2.4 and higher) software selectable NOTSCAN or SHUTTER MONITOR signal. Default is SHUTTER MONITOR. $\overline{\text{SCAN}}$, reports when the controller is finished reading out the CCD array. $\overline{\text{SCAN}}$ is high when the CCD array is not being scanned, then drops low when readout begins, returning to high when the process is finished. The second signal, SHUTTER MONITOR, reports when the shutter is opened and can be used to synchronize external shutters. SHUTTER MONITOR is low when the shutter is closed and goes high when the shutter is activated, dropping low again after the shutter closes. See Figure 46 for timing diagram.
6.	**$\overline{\text{READY}}$ Output:** Initially HIGH. After a Start Acquisition command, this output changes state on completion of the array cleaning cycles that precede the *first* exposure. Initially high, it goes low to mark the beginning of the *first* exposure. In free run operation it remains low until the system is halted. If a specific number of frames have been programmed, it remains low until all have been taken, then returns high.
7.	**Zero Adjustment:** (1 MHz and 100kHz/1 MHz systems) Control the offset values of the Fast (F) and Slow (S) A/D converters. Preadjusted at factory. The offset is a voltage that is added to the signal to bring the A/D output to a non-zero value, typically 50-100 counts. This offset value ensures that all the true variation in the signal can really be seen and not lost below the A/D "0" value. Since the offset is added to the signal, these counts only minimally reduce the range of the signal from 4095 to a value in the range of 50-100 counts lower. Adjusting a potentiometer clockwise increases the counts while rotating it counterclockwise decreases the counts. **CAUTION:** Do not adjust the offset values to zero, or some low-level data will be missed.
8.	**AUX Output:** Reserved for future use.
9.	**Detector Connector:** (1MHz and 1 MHz/100kHz systems) Transmits control information to the camera and receives data back from the camera via the Detector-Controller cable.
10.	**Serial COM Connector:** Provides two-way serial communication between the controller and the host computer. Contact the factory if an application requires use of the optional fiber-optic data link to increase the maximum allowable distance between the Camera and the computer.
11.	**Camera Signal:** (5 MHz system) Transmits control information to the camera and receives data back from the camera. The signal cable must be connected after the Camera Power cable is connected.

#	Feature
12.	**Camera Pwr:** (5 MHz system) Provides the power to operate the camera. The power cable must be connected before the Camera Signal cable is connected.
13.	**Fan:** Cools the controller electronics. Runs continuously when the controller is turned on. Do not block the side vents or the fan exhaust port.
14.	**Shutter Setting Selector:** Sets the shutter drive voltage. Dial is correctly set at the factory for the camera's internal shutter if one is present. Refer to Table 10 for setting selection. Note that this selector may not be available on the 5 MHz controller.
15.	**Remote Shutter Connector:** Provides shutter-drive pulses for an external shutter. Note that this selector may not be available on the 5 MHz controller. **WARNING:** Dangerous live potentials are present at the **Remote** Shutter Power connector. To avoid shock hazard, the Controller power should be OFF when connecting or disconnecting a remote shutter. **WARNING:** If the camera has an internal shutter, then the Shutter Power connector should not be used to drive a second *external* shutter. This configuration will result in under-powering both shutters and may cause damage to the system *In a system which requires both an internal and an external shutter, use the TTL Shutter Monitor signal (provided at the $\overline{SCAN}$ connector when selected by an internal jumper) to control the external shutter. Suitable driver electronics will additionally be required. Contact the factory Technical Support Dept. for information.*
16.	**Fuse/Voltage Label:** Displays the controller's power and fuse requirements.
17.	**Power Input Module:** Contains the powercord socket and two fuses. For more detailed information, see *Power Requirements* on page 18.

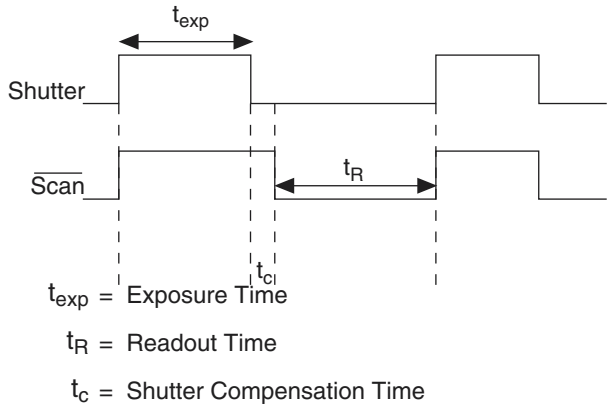
WARNING: Dangerous live potentials are present at the **Remote** Shutter Power connector. To avoid shock hazard, the Controller power should be OFF when connecting or disconnecting a remote shutter.

Setting	Shutter Type
1	External Shutter
2	25 mm (Small) Internal Shutter
4	35 mm Vincent Shutter (supplied with rectangular head camera having 1300 × 1340 CCD)
5	Large Internal Shutter

Table 10. ST-133 Shutter Drive Selection

WARNING

Selecting the wrong shutter setting will result in improper functioning of the shutter and may cause premature shutter failure.



Shutter Type	Compensation Time
NONE	200 nsec
Electronic	6.0 msec
Remote (Prontor 23)	8.0 msec
Small (Vincent 25 mm)	8.0 msec
Large (Vincent 35 mm)	28.0 msec

Figure 46. $\overline{SCAN}$ and SHUTTER MONITOR Signals

Cables

Detector-Controller: 1 MHz or 100kHz/1MHz systems. The standard 10' cable has DB-25 Male connectors with slide-latch locking hardware. This cable interconnects the Detector connector on the rear of the ST-133 with the Detector connector on the back of the MicroMAX camera. The Detector-Controller cable is also available in 6', 15', 20', and 30' lengths.

Camera Power & Signal: 5 MHz systems only. This cable assembly consists of two cables that interconnect the Camera Power and Camera Signal connectors on the back of the ST-133 with the mating connectors on the back of the camera. The Camera Power cable has DB-15 Male connectors with sliding-latch locking mechanisms at both ends. The Camera Signal cable has DB-40 Male connectors with spring-latch locking mechanisms at both ends.

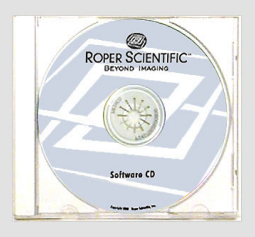
TAXI: The standard 25' cable has DB-9 Male connectors with screw-down locking hardware. The TAXI (Serial communication) cable interconnects the "Serial Com" connector on the rear of the ST-133 with the PCI card installed in the host computer. This cable is also available in 10', 50', 100', and 165' lengths.

Interface Card

PCI Card: The standard interface card plugs-into the host computer's motherboard and provides the serial communication interface between the host computer and the ST-133. Through WinView/32, the card can be used in either **High Speed PCI** or **PCI(Timer)** mode. **High Speed PCI** allows data transfer to be interrupt-

driven and can give higher performance in some situations. **PCI(Timer)** allows data transfer to be controlled by a polling timer.

Application Software



The Princeton Instruments WinView/32 software package provides comprehensive image acquisition, display, processing, and archiving functions so you can perform complete data acquisition and analysis without having to rely upon third-party software. WinView/32 provides reliable control over all Roper Scientific detectors, regardless of array format and architecture, via an exclusive universal programming interface (PVCAM®). WinView/32 also features snap-ins and macro record functions to permit easy user customization of any function or sequence.

PVCAM is the standard software interface for cooled CCD cameras from Roper Scientific. It is a library of functions that can be used to control and acquire data from the camera when a custom application is being written. For example, in the case of Windows, PVCAM is a dynamic link library (DLL). Also, it should be understood that PVCAM is solely for camera control and image acquisition, not for image processing. PVCAM places acquired images into a buffer, where they can then be manipulated using either custom written code or by extensions to other commercially available image processing packages.

User Manuals

MicroMAX System User Manual: This manual describes how to install and use the MicroMAX system components.

WinView/32 User Manual: This manual describes how to install and use the WinView/32 application program. A PDF version of this manual is provided on the installation CD. Additional information is available in the program's on-line help.

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Chapter 10
Troubleshooting

WARNING! Do not attach or remove any cables while the MicroMAX system is powered on.

Introduction

The following issues have corresponding troubleshooting sections in this chapter.

Baseline Signal Suddenly Changes	Page 89
Changing the ST-133's Line Voltage and Fuses	Page 89
Controller Is Not Responding	Page 90
Cooling Troubleshooting	Page 91
Detector Stops Working	Page 92
Error occurs at Computer Powerup	Page 92
Removing/Installing a Plug-In Module	Page 95
Shutter Malfunctions	Page 96

Baseline Signal Suddenly Changes

If you observe a sudden change in the baseline signal, you may have excessive humidity in the vacuum enclosure of the detector. Turn off the controller and have the detector repumped before resuming normal operation. *Contact the factory Technical Support Dept. for information on how to refresh the vacuum. See page 125 for contact information.*

Changing the ST-133's Line Voltage and Fuses

The appropriate voltage setting for your country is set at the factory and can be seen on the power input module. If your voltage source changes, you will need to change the voltage setting and you may need to change the fuse configuration.

WARNING Use proper fuse values and types for the controller and detector to be properly protected.

To Change Voltage and Fuse Configuration:

WARNING Before opening the power input module, turn the Controller OFF and unplug the line cord.

1. As shown in Figure 47, place the flat side of a flat bladed screwdriver parallel to the rear of the Controller and behind the small tab at the top of the power input module, and twist the screwdriver slowly but firmly to pop the module open.
2. To change the voltage setting, roll the selector drum until the setting that is closest to the actual line voltage is facing outwards.
3. Confirm the fuse ratings by removing the two white fuse holders. To do so, simply insert the flat blade of the screwdriver behind the front tab of each fuse holder and gently pry the assembly out.

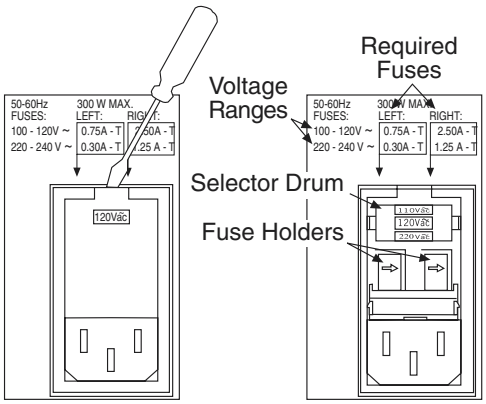

Figure 47. Power Input Module

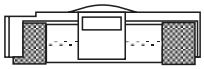

Figure 48. Fuse Holder

4. After inspecting and if necessary, changing the fuses to those required by the selected voltage, reinstall the holders with the arrow facing to the right.
5. Close the power input module and verify that the correct voltage setting is displayed.
6. Verify that the Controller power switch is in the OFF position and then plug the powercord back into the power input module.

Controller Is Not Responding

If this message pops up when you click on **OK** after selecting the "Interface Type" during **Hardware Setup** (under the WinView/32 **Setup** menu), the system has not been able to communicate with the Controller. Check to see if Controller has been turned ON and if the interface card, its driver, and the interface cable have been installed.

- If the Controller is ON, the problem may be with the interface card, its driver, interrupt or address conflicts, or the cable connections.
- If the interface card is not installed, close WinView/32 and turn the Controller OFF. Follow the interface card installation instructions in provided with your interface card and cable the card to the SERIAL COM port on the rear of the Controller. Then do a "Custom" installation of WinView/32 with the appropriate interface component selected: "PCI Interface" or "ISA Interface", depending on the interface card type. Be sure to deselect the interface component that does not apply to your system.

  Note: WinView/32 (versions 2.5.0 and higher) do not support the ISA interface.

- If the interface card is installed in the computer and is cabled to the SERIAL COM port on the rear of the Controller, close WinView/32 and turn the Controller OFF. Check the cable connections and tighten the locking screws if the connections are loose.
- If the interface card was installed after WinView/32 has been installed, close WinView/32 and do a "Custom" installation of WinView/32 with the appropriate

interface component selected: "PCI Interface" or "ISA Interface", depending on the interface card type. Be sure to deselect the interface component that does not apply to your system.

Note: WinView/32 (versions 2.5.0 and higher) do not support the ISA interface.

Cooling Troubleshooting

Temperature Lock cannot be Achieved or Maintained.

Possible causes could include:

- The vacuum has deteriorated and needs to be refreshed.
- The connectors of the cable that interconnects the controller and the detector need to be secured.
- The target array temperature is not appropriate for your particular detector and CCD array.
- For a TE-cooled detector, the detector's internal temperature may be too high, such as might occur if the operating environment is particularly warm or if you are attempting to operate at a temperature colder than the specified limit. TE-cooled detectors are equipped with a thermal-protection switch that shuts the cooler circuits down if the internal temperature exceeds a preset limit. Typically, detector operation is restored automatically in about ten minutes. Although the thermo-protection switch will protect the detector, you are nevertheless advised to power down and correct the operating conditions that caused the thermal-overload to occur.

Detector loses Temperature Lock

The internal temperature of the detector is too high. This might occur if the operating environment is particularly warm or if you are trying to operate at a temperature colder than the specified limit. If this happens, an internal thermal overload switch will disable the cooler circuits to protect them. Typically, detector operation is restored in about ten minutes. Although the thermal overload switch will protect the detector, users are advised to power down and correct the operating conditions that caused the thermal overload to occur. *With some versions of the software, the **indicated** temperature when the detector is in thermal overload (thermal switch is in the cut-out state) is -120° C.*

Gradual Deterioration of Cooling Capability

With time, there will be a gradual deterioration of the detector's vacuum. This, in turn, will eventually affect temperature performance and it may no longer be possible to achieve temperature lock at the lowest temperatures. In the kind of low-light applications for which cooled CCD detectors are so well suited, it is highly desirable to maintain the system's temperature performance because lower temperatures provide less thermal noise and better signal-to-noise ratio.

Vacuum deterioration occurs primarily as a result of outgassing of components in the vacuum chamber. Because outgassing normally diminishes with time, the rate of vacuum deterioration in new detectors will be faster than in old ones. When the detector no longer maintains an acceptable cold temperature, *contact the factory Technical Support Dept. to make arrangements for returning the detector to have the vacuum restored. See page 125 for contact information.*

WARNING! Do not open the vacuum valve under any circumstances. Opening the vacuum valve will void your warranty.

Detector Stops Working

Problems with the host computer system or software may have side effects that appear to be hardware problems. If you are sure the problem is in the MicroMAX system hardware, begin with these simple checks:

- Turn off all AC power.
- Verify that all cables are securely fastened and that all locking screws are in place.
- Check for a burned-out fuse in the Controller power input module. For information about changing a fuse, see " Changing the ST-133's Line Voltage and Fuses" on page 89.
- Correct any apparent problems and turn the system on.

If the system still does not respond, contact Technical Support.

Error occurs at Computer Powerup

If an error occurs at boot up, either the interface card is not installed properly or there is an address or interrupt conflict. Turn off the computer, reinstall the interface card (make sure it is firmly seated), and reboot the system.

If an error occurs while you are using the WinView/32 program, check the interface selection on the **Hardware Setup|Interface** tab page (WinView/32). If the current choice is "High Speed PCI", change the selection to "PCI(Timer)". If the problem goes away, you can either correct the interrupt conflict or you can continue using PCI(Timer) for data transfer (data transfer is controlled by a polling timer rather than interrupts). Note that data transfer can be slower in PCI(Timer) mode on slower computers.

Conflicts

One of the many advantages that PCI offers over ISA is that the whole issue of address and interrupt assignments is user transparent and under BIOS control. As a result, users typically do not have to be concerned about jumpers or switches when installing a PCI card. Nothing more should be required than to plug in the card, make the connections, and operate the system. As it turns out, however, in certain situations conflicts may nevertheless occur and user intervention will be required to resolve them.

Typical PCI motherboards have both ISA and PCI slots and will have both PCI and ISA cards installed. In the case of the ISA cards, the I/O address and Interrupt assignments will have been made by the user and the BIOS will not know which addresses and interrupts have been user assigned. When a PCI card is installed, the BIOS checks for available addresses and interrupt levels and automatically assigns them so that there are no *PCI* address or interrupt conflicts. However, because the BIOS doesn't know about the user-assigned ISA I/O address and interrupt level assignments, it is possible that a PCI card will be assigned an address or interrupt that is already assigned to an ISA card. If this happens, improper operation will result. Specifically, the problems could range from erratic operation under specific conditions to complete system failure. If such a

conflict occurs, because the user has no control over the PCI address and interrupt assignments, there will be no recourse but to examine the .ISA assignments and change them to values which do not conflict. Most (but by no means all) ISA cards make provision for selecting alternative I/O addresses and interrupt levels so that conflicts can be resolved. Software is available to help identify specific conflicts.

The following example may serve to illustrate the problem. Suppose you had a system with an ISA network card, a PCI video card and an ISA sound card. Further suppose that you were then going to install a PCI Serial Buffer card. Before installing the PCI Serial card, the I/O address and interrupt assignments for the installed cards might be as follows.

Slot Type	Status	I/O Address	Interrupt
1 (ISA)	ISA Network Card	200-210	11
2 (PCI)	PCI Video Card	FF00-FFFF	15
3 (ISA)	ISA Sound Card	300-304	9
4 (PCI)	Empty	N/A	N/A

Table 11. I/O Address & Interrupt Assignments before Installing Serial Card

As shown, there are no conflicts, allowing the three peripheral cards to operate properly. If the PCI Serial card were then installed, the BIOS would interrogate the PCI cards and may reassign them new address and interrupt values as follows.

Slot Type	Status	I/O Address(s)	Interrupt
1 (ISA)	ISA Network Card	200-210	11
2 (PCI)	PCI Video Card	FE00-FEFF	11
3 (ISA)	ISA Sound Card	300-304	9
4 (PCI)	Princeton Instruments PCI Serial Card	FF80-FFFF	15

Table 12. I/O Address & Interrupt Assignments after Installing Serial Card

As indicated, there is now an interrupt conflict between the ISA Network Card and the PCI Video card (both cards have been assigned Interrupt 11), causing the computer to no longer function normally. This doesn't mean that the PCI Serial card is defective because the computer stops functioning properly when the Serial card is installed. What it does mean is that there is an interrupt conflict that can be resolved by changing the interrupt level on the conflicting Network card in this example. It is up to the user to consult the documentation for any ISA cards to determine how to make the necessary change.

Note: Changing the order of the PCI cards, that is, plugging them into different slots, could change the address and interrupt assignments and possibly resolve the conflict. However, this would be a trial and error process with no guarantee of success.

Diagnostics Software

Many diagnostics programs, both shareware and commercial, are available to help resolve conflicts. Most often, all that's required is a program that will read and report the

address and interrupt assignments for each PCI device in the computer. One such program available from Roper Scientific's Technical Support department is called PCICHECK. When the program is run, it reports the address and interrupt assignments for the first PCI device it finds. Each time the spacebar is pressed, it moves on to the next one and reports the address and interrupt assignments for that one as well. In a few moments this information can be obtained for every PCI device in the computer. Note that, even though there are generally only three PCI slots, the number of PCI devices reported may be larger because some PCI devices may be built onto the motherboard. A good strategy for using the program would be to run it before installing the PCI Serial card. Then run it again after installing the card and note any address or interrupt assignments that may have changed. This will allow you to easily focus on the ones that may be in conflict with address or interrupt assignments on ISA cards. It might be noted that there are many programs, such as the MSD program supplied by Microsoft, that are designed to read and report address and interrupt assignments, including those on ISA cards. Many users have had mixed results at best using these programs.

Operation

There are no operating considerations that are unique to the PCI Serial card. The card can easily accept data as fast as any Princeton Instruments system now available can send it. The incoming data is temporarily stored in the card's memory, and then transferred to the main computer memory when the card gains access to the bus. The PCI bus arbitration scheme assures that, as long as every PCI card conforms to the PCI guidelines, the on-board memory will never overflow.

Unfortunately, there are some PCI peripheral cards that do ***not*** fully conform to the PCI guidelines and that take control of the bus for longer periods than the PCI specification allows. Certain video cards (particularly those that use the S3 video chip) are notorious in this respect. Usually you will be able to recognize when memory overflow occurs because the displayed video will assume a split-screen appearance and/or the message **Hardware Conflict** will be displayed (WinView/32). At the same time, the LED on the upper edge of the PCI Serial card will light.

Users are thus advised not to take any actions that would worsen the possibility of memory overflow occurring when taking data. In that regard, avoid multitasking while taking data. Specific operations to avoid include multitasking (pressing ALT TAB or ALT ESC to start another program), or running a screensaver program.

Removing/Installing a Plug-In Module

The ST-133 Controller has three plug-in slots. The Analog/Control module (leftmost slot when the controller is viewed from the rear) and the Interface Control module (middle slot) are always provided. The third slot, however, is always covered with a blank panel.

If a module is ever removed for any reason, internal settings should ***not*** be disturbed. Changing a setting could radically alter the controller's performance. Restoring normal operation again without proper equipment and guidance would be very difficult, and it might be necessary to return the unit to the factory for recalibration.

WARNING

Always turn the Controller OFF before removing or installing a module. If a module is removed or installed when the controller is powered, permanent equipment damage could occur which would not be covered by the warranty.

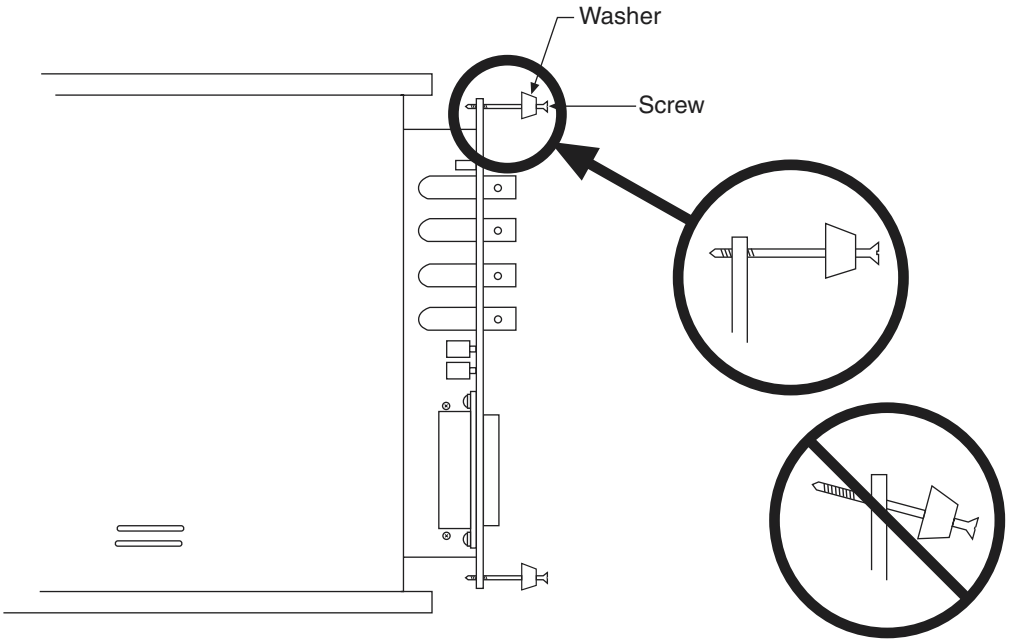

Figure 49. Module Installation

To Remove a Module:

1. Verify that the Controller has been turned OFF.
2. Rotate the two locking screws (one at the top of the module and one at the bottom) counterclockwise until they release from the chassis.
3. Then, grasp the module and pull it straight out.

To Install a Module:

Installing a module is a bit more complex because you first have to be sure the locking screws are aligned correctly. The following procedure is suggested.

1. Rotate the two locking screws counterclockwise until the threads on the screws engage those of the module panel. *See Figure 49.* By doing this, the screws will be perfectly perpendicular to the module panel and will align perfectly when the module is inserted.
2. Insert the module so that the top and bottom edges of the board are riding in the proper guides.
3. Gently but firmly push the module in until the 64-pin DIN connector at the rear of the module mates with the corresponding connector on the backplane, leaving the module panel resting against the controller back panel.
4. Rotate the two locking screws clockwise. As the screws are rotated, they will first disengage from the module panel threads, and then begin to engage those of the bracket behind the controller panel.

WARNING

Tighten the screws to where they are just snug. Do ***not*** tighten them any further because you could easily bend the mating bracket.

Shutter Malfunctions

- Verify that the correct shutter setting has been selected on the rear of the Controller. Refer to Table 10 on page 85.
- If you are using a 25 mm remote-mounted shutter and it suddenly stops running, its built-in thermal interlock may have been triggered. Stop the experiment and wait. The shutter should resume functioning when it has cooled down sufficiently, typically within an hour. Avoid repeating the conditions (such as high repetition rate) that lead to the shutter overheating, or take breaks between data collections.
- If the shutter no longer operates at all, sticks open or closed causing overexposed or smeared images, or a shutter leaf has broken and no longer actuates, contact the factory to arrange for a shutter-replacement repair. Note that shutters are not covered by the warranty.

Appendix A
Specifications

CCD Arrays

Spectral Range

Typically: 370-900 for MicroMAX:512BFT and 1024B
400-1000 for MicroMAX:782Y, 782YHS
300-1080 for MicroMAX:1300Y, 1300YHS, and 1300YHS-DIF

Types

The following list is not necessarily current. Other chips may also be available. Contact the factory for up-to-date information.

Model	CCD (WinView/32 Name)	Pixel Format	Pixel Size	CCD Type
512BFT	EEV CCD57-10 (EEV 512×512 FT CCD57)	512 × 512	13 × 13 µm	100 kHz/1 MHz, Back-illuminated, Frame transfer
782Y	Sony ICX075 (PID 582×782)	782 × 582	8.3 × 8.3 µm	1 MHz, Interline
782YHS	Sony ICX075 (PID 582×782)	782 × 582	8.3 × 8.3 µm	5 MHz, Interline
1024B	EEV 47-10 (EEV 1024×1024 CCD47_10)	1024 × 1024	13 × 13 µm	100 kHz/1 MHz, Back-illuminated, Full-frame
1300Y	Sony ICX061 (PID 1030×1300)	1300 × 1030	6.7 × 6.7 µm	1 MHz, Interline
1300YHS	Sony ICX061 (PID 1030×1300)	1300 × 1030	6.7 × 6.7 µm	5 MHz, Interline
1300YHS-DIF	Sony ICX061 (PID 1030×1300)	1300 × 1030	6.7 × 6.7 µm	5 MHz, Interline, DIF

Temperature Control

Setting Mechanism: Temperature is set by the application software.

Display: The actual temperature can be displayed at the computer by the application software.

Range: At 25° ambient, the MicroMAX camera will typically lock to:

- -15°C with passive cooling and with the camera under vacuum.
- -30°C with the accessory fan installed and under vacuum.

Time to Lock: At 25° ambient, <10 minutes (typical) to temperature lock at -15° C

Control Precision: ±0.050°C over entire temperature range

Cooling

Passive: CCD array cooled by Peltier device. Heat is radiated away by cooling fins on body of the round head camera.

Supplemental Air Cooling: The rectangular head camera has an internal fan that draws air in from the vents in the camera shell, circulates it past the internal cooling fins, and then exhausting the warmed air back into the atmosphere.

Mounting

Camera: There are four ¼″ x 20 UNC 3/8″ deep threaded holes on the body of the camera to facilitate mounting.

Lens: Camera will accept either "C-mount" (threaded) or "F-mount" (bayonet) lenses, according to the mount specified at time of order.

Microscope: Adapters are available for mounting to most research microscopes. See Chapter 3 for more information.

Shutters

The round head camera does not have an internal shutter. The rectangular head camera is supplied with either a 25 mm internal shutter (C-mount) or a 35 mm internal shutter (F-mount).* The Shutter Compensation times listed below are based on the values used by the WinView/32 program.

Shutter	Shutter Compensation Time
None	200 nsec
Electronic	6.0 msec
Remote (Prontor 23 mm)	8.0 msec
Small (Vincent 25 mm)	8.0 msec
Large (Vincent 35 mm)	28.0 msec

* The 35 mm shutter requires a controller having the 70 V shutter drive modification. Controllers having this option cannot be used with cameras with the 25 mm shutter.

Inputs

EXT SYNC: TTL input (BNC) to allow data acquisition to be synchronized with external events. Sense can be positive or negative going as set in software. Synchronization and Trigger Modes are discussed in Chapter 5.

Outputs

VIDEO: 1 V pk-pk from 75 Ω, BNC connector. Either RS-170 (EIA) or CCIR standard video as specified when system was ordered. Requires connection via 75 Ω cable that must be terminated into 75 Ω.

$\overline{\text{SCAN}}$: TTL output (BNC) for monitoring camera status. TTL low when CCD is being read; otherwise high. *An internal jumper allows selection of alternative SHUTTER MONITOR signal.* Default selection is SHUTTER MONITOR. *Contact the factory Technical Support Dept. for information on changing the jumper setting. See page 123 for contact information.*

SHUTTER MONITOR: Alternative signal to $\overline{\text{SCAN}}$ as selected by internal jumper. Precisely brackets shutter-open time (exclusive of shutter compensation) and can be used to control an external shutter.

$\overline{\text{READY}}$: TTL output (BNC); marks start of *first* exposure. When run is initiated, remains high until completion of cleaning cycles preceding *first* exposure, then goes low and remains low for duration of run.

SERIAL COMM: Data link to computer via proprietary cable connected to this 9-pin "D" connector. Cable lengths to 165 feet (50 m) available.

Programmable Interface

TTL I/O at DB25 connector. There are eight input bits and eight output bits as described in Appendix B.

A/D Converter

Converter range: 12 bits

Readout Rate: Fast, 1 MHz (alternatively 500 kHz); Slow, 100 kHz. Contact factory for information on other A/D converters.

Linearity: better than 1%.

Readout noise: 1-1.3 counts RMS on standard systems

Exposure (integration time): 5 msec to 23 hours (full frame or frame transfer)

Computer Requirements

The MicroMAX is most commonly used with a Pentium computer configured as follows.

Type: Any Pentium (or better) PC having a free slot for the Serial Buffer card (PCI is standard; other types may be available).

Memory (RAM): Minimum of 32 Mbytes; possibly more depending on experiment design and size of CCD Array.

Operating System: Windows 95 or NT for WinView/32. *Windows 3.1 required for 16 bit versions of WinView.*

Interface: PCI High-Speed Serial I/O card is standard. Other types may be available. Contact factory for information.

Note: Macintosh II support may be available. Contact factory for details.

Miscellaneous

Dimensions: See Appendix A.

Camera Weight:

Round Head: 3 lb max (1.58 kg) for C-mount; 3.5 lb (1.35 kg) max for F-mount,

Rectangular Head: 7 lb (3.2 kg) max for C-mount; 7 lb (3.2 kg) max for F-mount,

Controller Weight: 12 lb (5.4 kg) max

Power Requirements: Nominally 100,120, 220 or 240 V AC , 47-63 Hz, 200 watts; required DC voltages are generated in the controller. Power to camera is applied via controller cable.

Environmental Requirements: Storage temperature ≤50° C; Operating temperature range over which specifications can be met is 18° C to 23° C; Relative humidity ≤50% noncondensing.

TTL Requirements: Rise time ≤ 40 nsec, Duration ≥ 100 nsec.

Appendix B
Outline Drawings

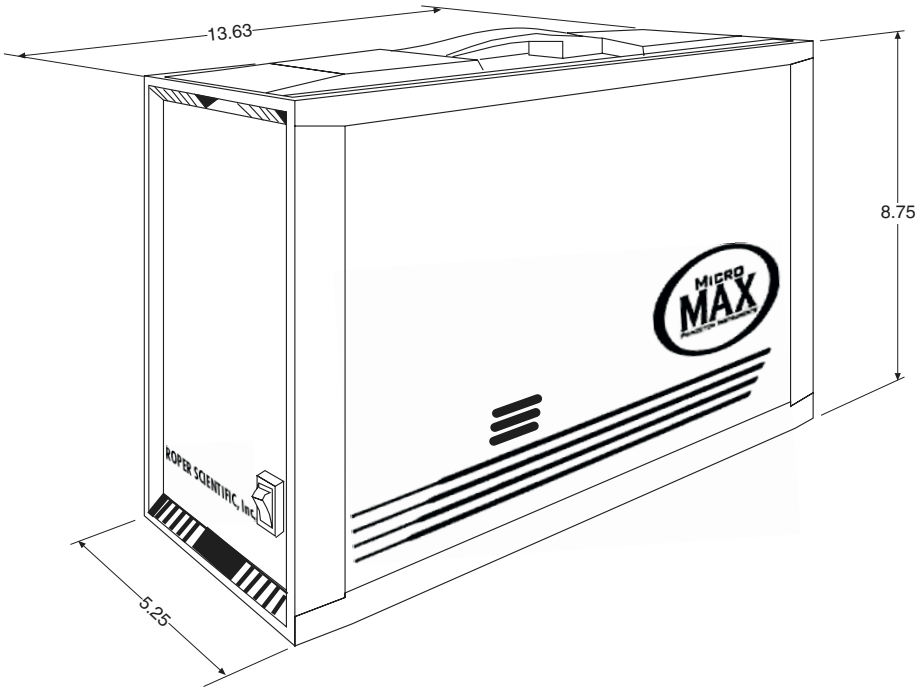

Figure 50. Controller Dimensions

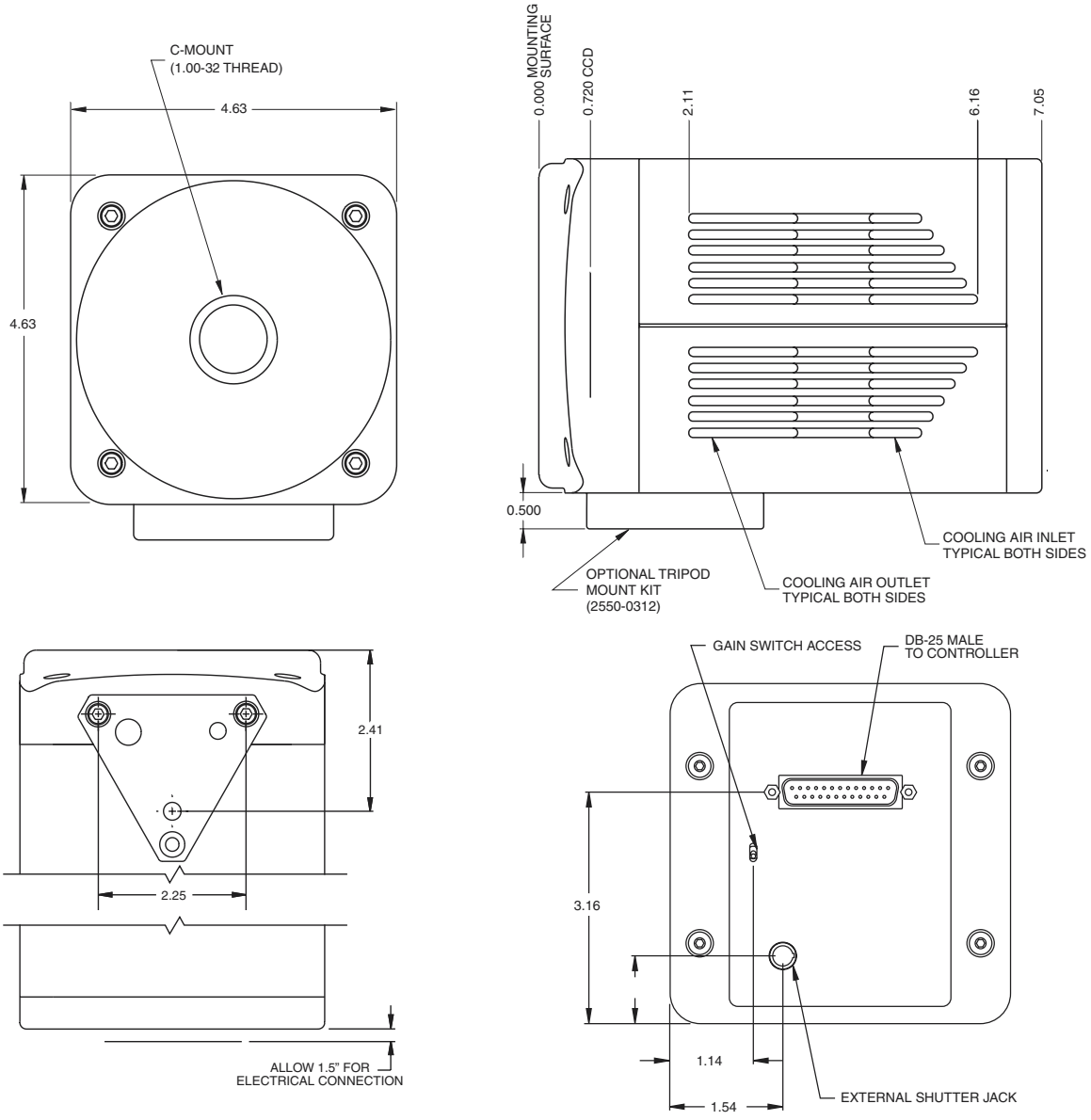

Figure 51. Rectangular Camera Head: C-Mount

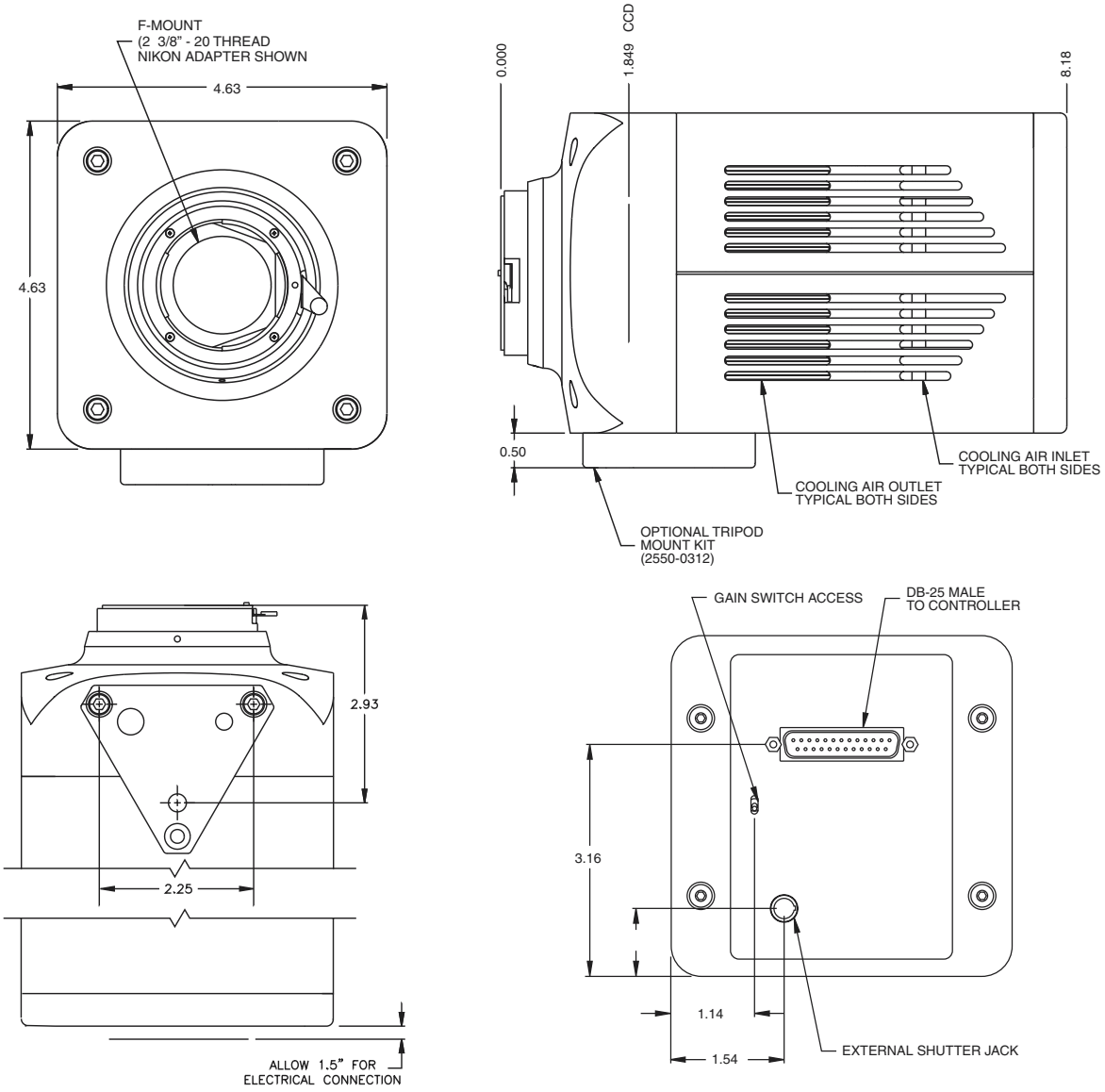

Figure 52. Rectangular Camera Head: F-Mount

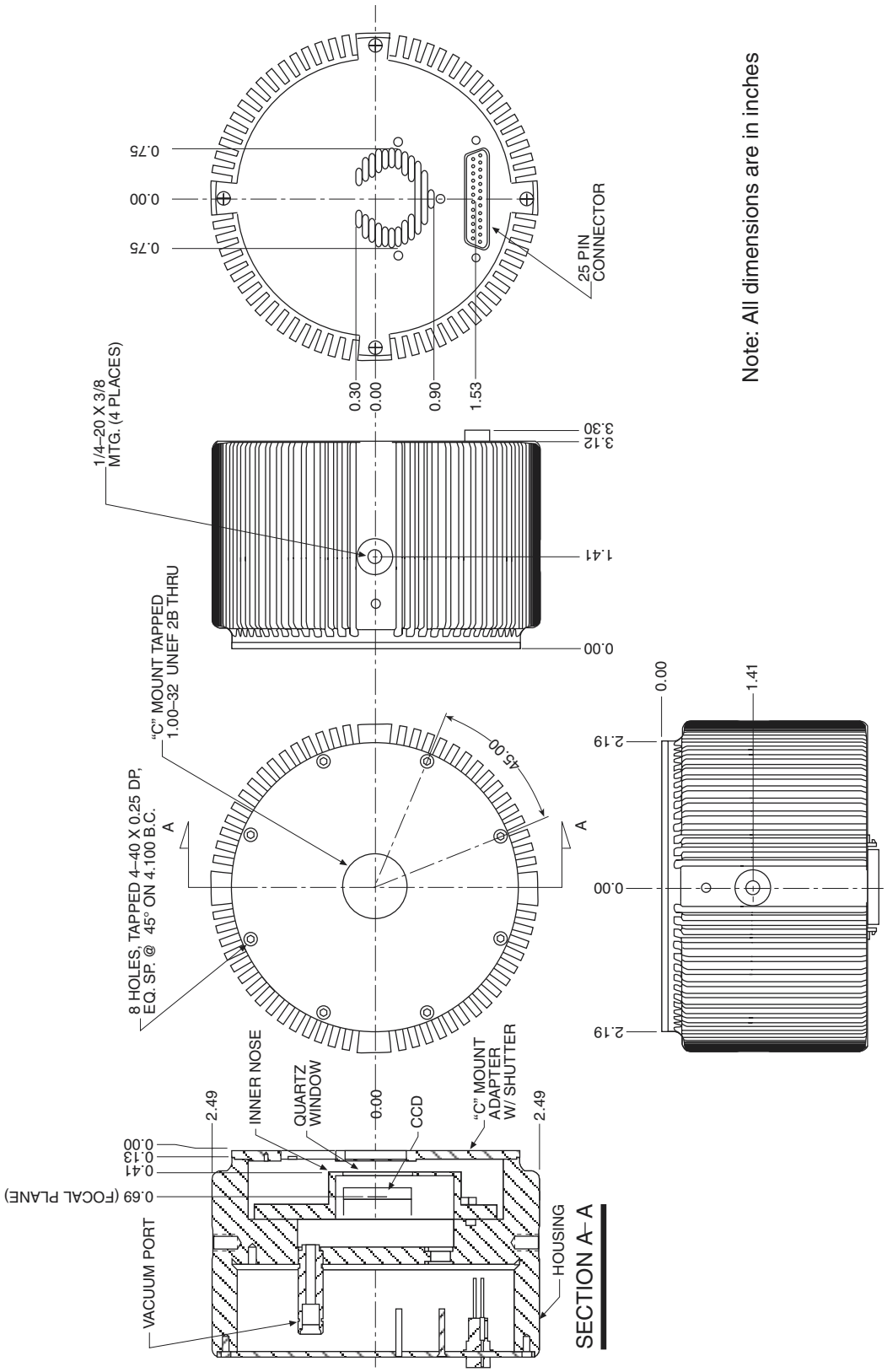

Figure 53. 1 MHz and 100kHz/1MHz Round Head Camera: C-Mount Adapter and Shutter

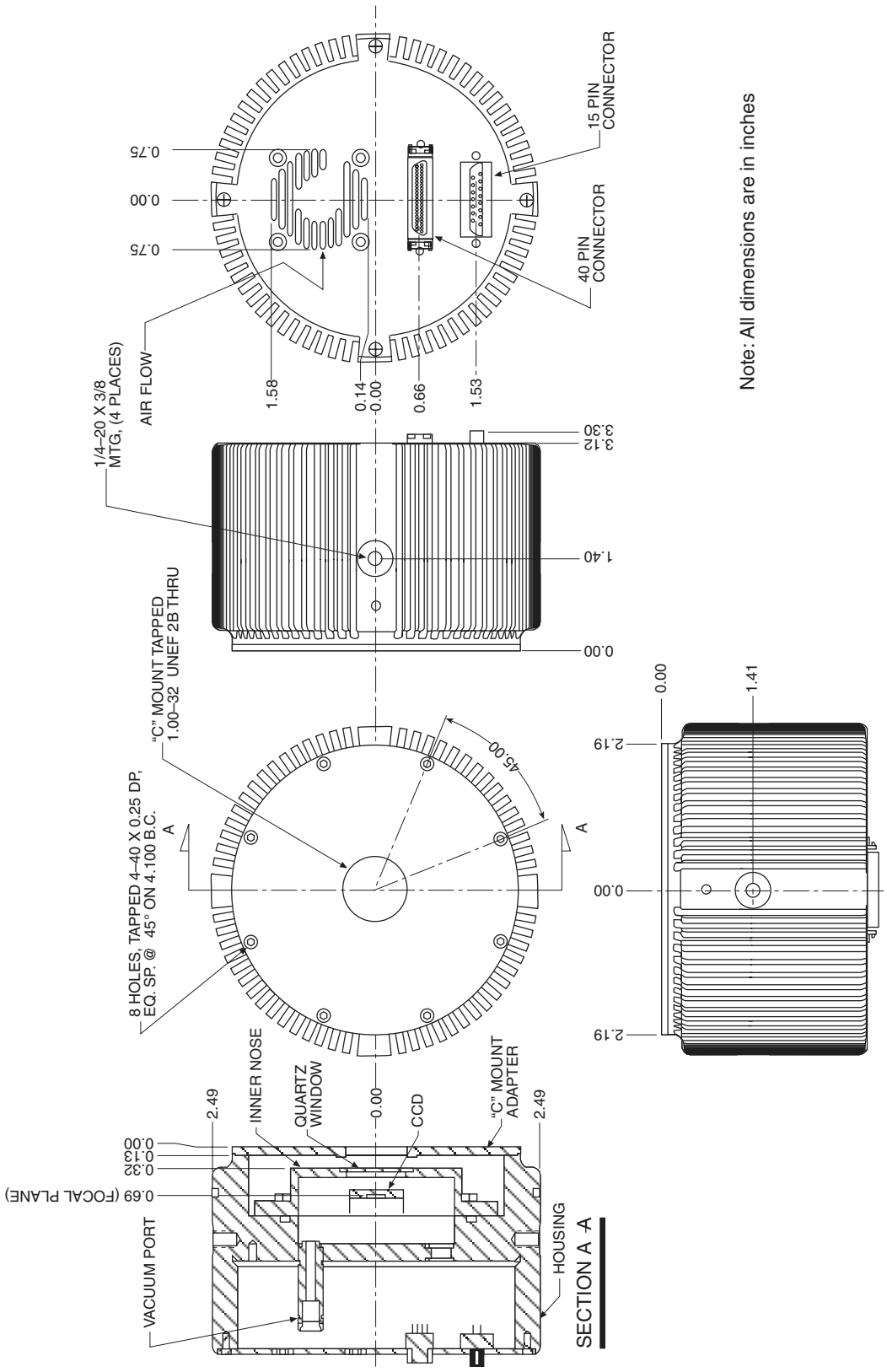

Figure 54. 5 MHz Round Head Camera: C-Mount Adapter

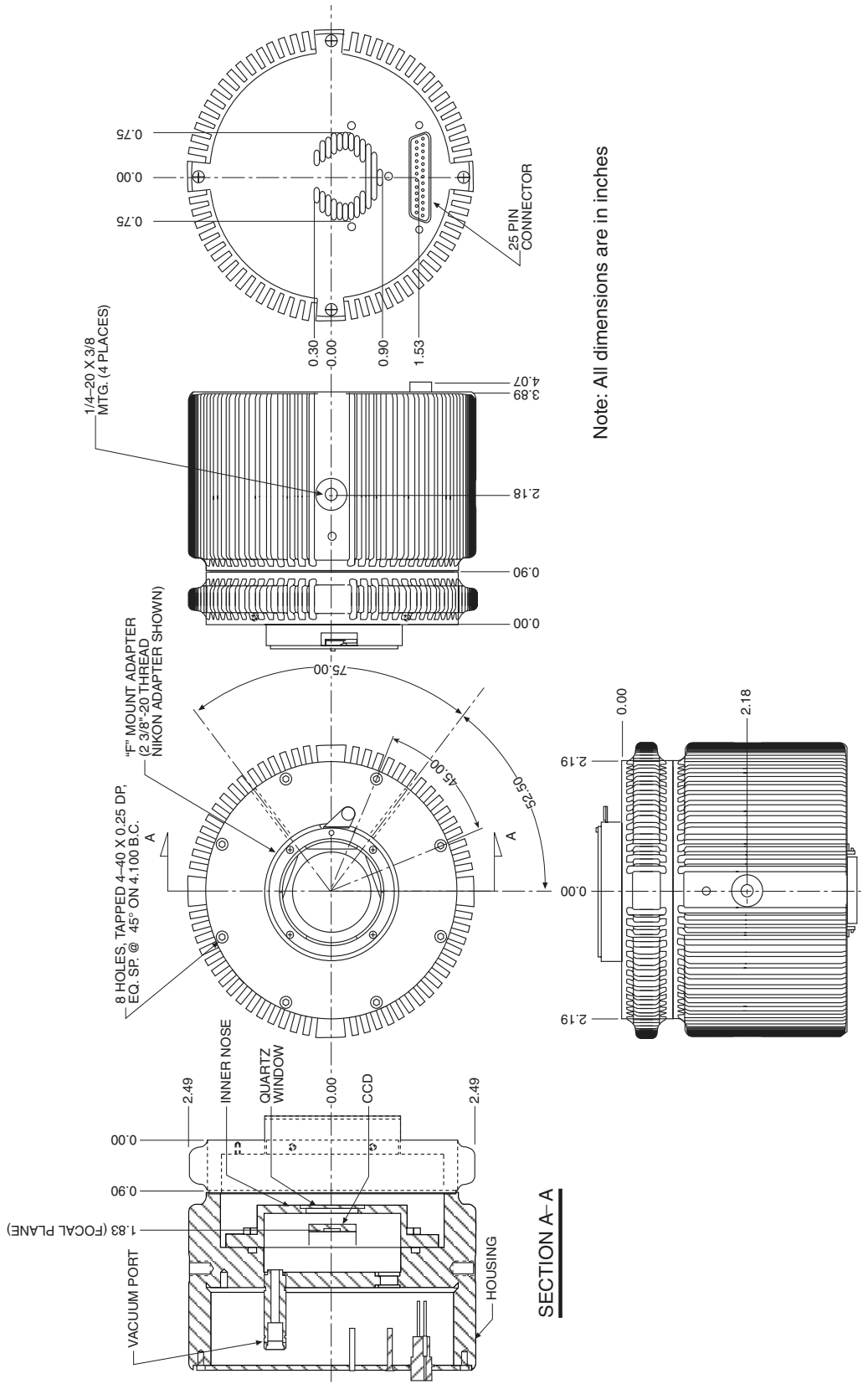
Note: All dimensions are in inches
25 PIN CONNECTOR
1/4–20 X 3/8 MTG. (4 PLACES)
"F" MOUNT ADAPTER (2 3/8"-20 THREAD NIKON ADAPTER SHOWN)
8 HOLES, TAPPED 4–40 X 0.25 DP, EQ. SP. @ 45° ON 4.100 B.C.
INNER NOSE
QUARTZ WINDOW
CCD
HOUSING
VACUUM PORT
1.83 (FOCAL PLANE)
SECTION A–A

Figure 55. 1 MHz Round Head Camera: F-Mount Adapter

Appendix C
Kinetics Mode

Introduction

Kinetics mode uses the CCD to expose and store a limited number of images in rapid succession. The time it takes to shift each line (or row) on the CCD is as short as a few hundred nanoseconds to few microseconds, depending on the CCD. Therefore the time between images can be as short as a few microseconds. Kinetics mode allows frame transfer CCDs to take time-resolved images/spectra.

Note: Kinetics mode is an option, so the controller must be programmed before your order is shipped. If the Kinetics option has been installed in the ST-133, this readout mode will be made available when you select the appropriate camera type on the **Hardware Setup** dialog box.

Below is a simplified illustration of kinetics mode. Returning to our 4 × 6 CCD example, in this case 2/3 of the array is masked, either mechanically or optically. The shutter opens to expose a 4 × 2 region. While the shutter remains open, charge is quickly shifted just under the mask, and the exposure is repeated. After a third image is collected the shutter is closed and the CCD is read out. Since the CCD can be read out slowly, very high dynamic range is achieved. Shifting and readout are shown in Figure 56.

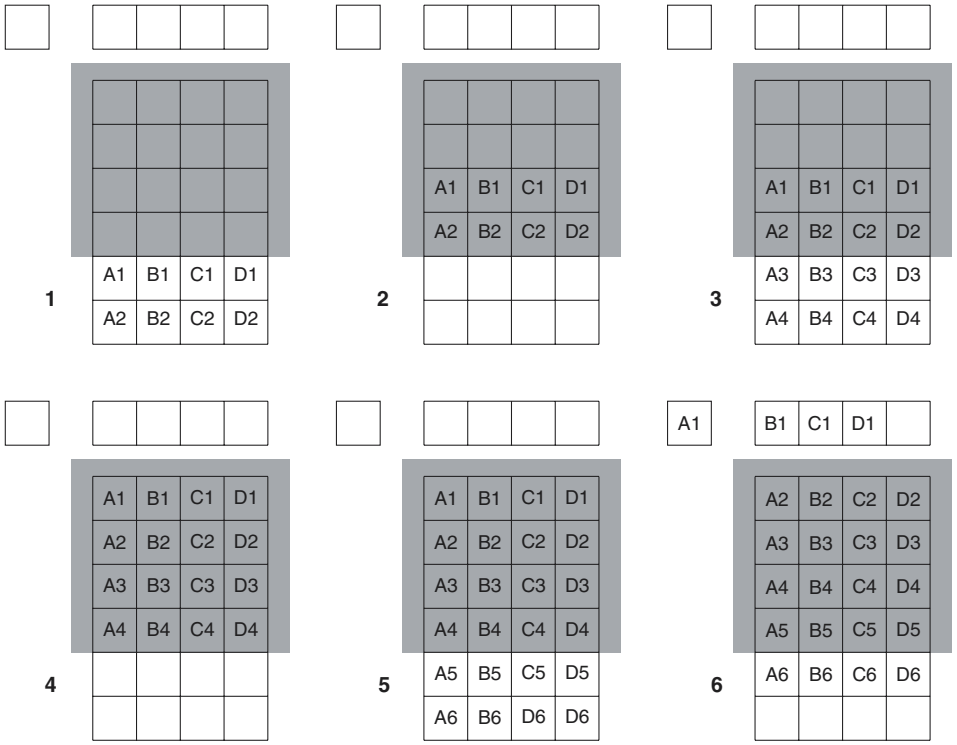

Figure 56. Kinetics Readout

Kinetic Timing Modes

Kinetics mode operates with three timing modes: Free Run, Single Trigger, and Multiple Trigger.

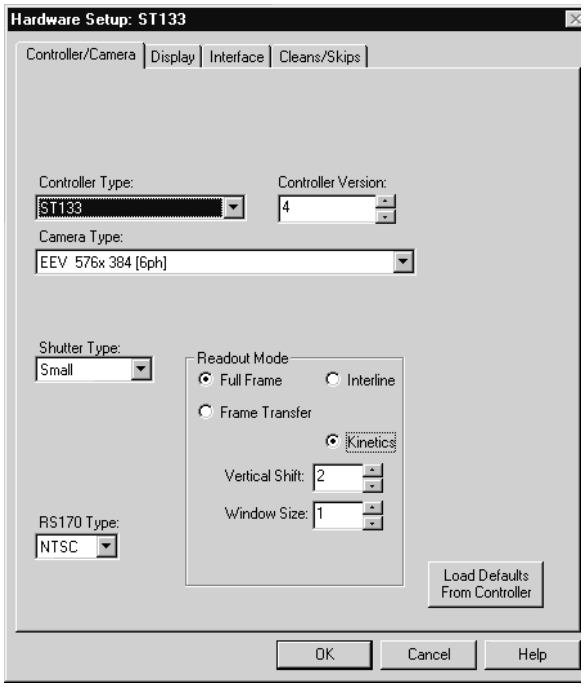

Figure 57. Hardware Setup dialog box

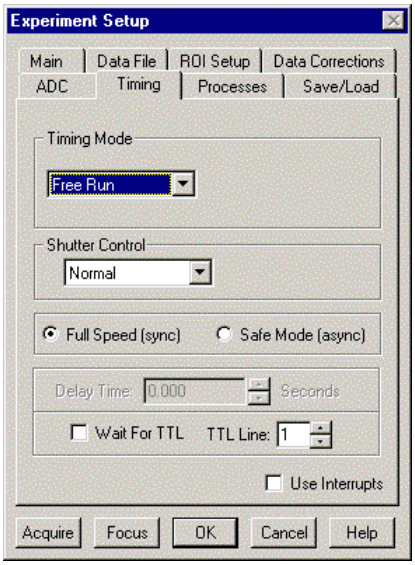

Figure 58. Experiment Setup dialog box

Free Run

In the Free Run Kinetics mode, the controller takes a series of images, each with the Exposure time set through the software (in WinView32, the exposure time is set on the **Experiment Setup|Main** tab page). The time between image frames, which may be as short as a few microseconds, is limited by the time required to shift an image under the mask: this interimage time equals the Vertical Shift rate (specified in μsec/row) multiplied by the Window Size (the number of rows allocated for an image frame). The exact number of frames depends on the selected Window Size and is equal to the number of pixels perpendicular to the shift register divided by the Window Size.

Example: Referring to the readout shown in Figure 56, there are 6 pixels perpendicular to the shift register and the Window Size is 2 pixels high. The number of frames is 3. If the Vertical Shift Rate for the CCD is 1.6 μsec/row, the Shift time will be 3.2 μsec per frame.

Integrate signals (Shutter Monitor) or Readout signals (NOT SCAN) are provided at the $\overline{\text{SCAN}}$ BNC for timing measurements

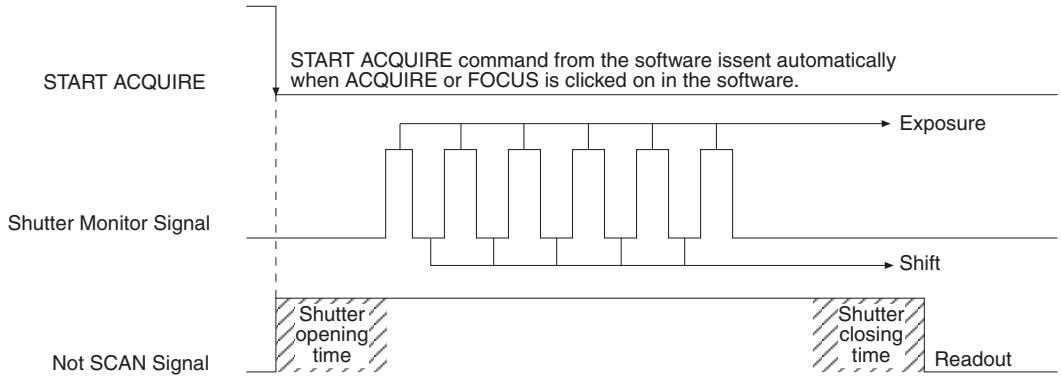

Figure 59. Free Run Timing Diagram

Single Trigger

Single Trigger Kinetics mode takes an entire series of images with each External Trigger Pulse (applied at the Ext. Sync BNC on the control board of ST133). After the series is complete the shutter closes and the CCD is read out at normal speeds. Once the readout is complete the detector is ready for the next series of exposures. This timing is shown in Figure 60, where a single External trigger pulse is used to collect a burst of 6 frames.

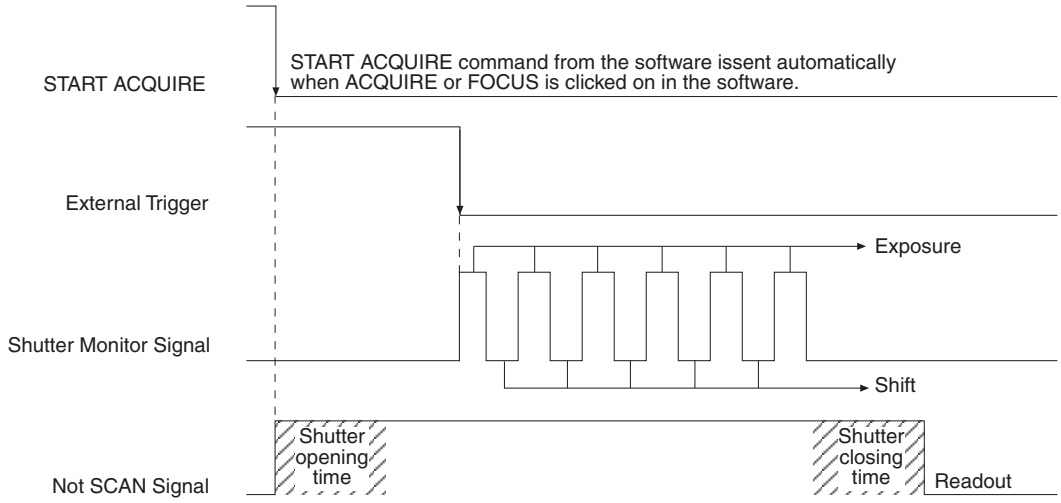

Figure 60. Single Trigger Timing Diagram

Multiple Trigger

Multiple Trigger Kinetics mode takes a single image in the series for each External Sync pulse received by the controller. Once the series is complete the shutter closes and readout begins. Since the shutter is open during the entire series of images, if the External Sync pulses are irregularly spaced then the exposures will be of different lengths. Once the series has been read out the detector is ready for the next series. This timing is shown in Figure 61, where a series of 6 frames is collected with 6 External Sync pulses.

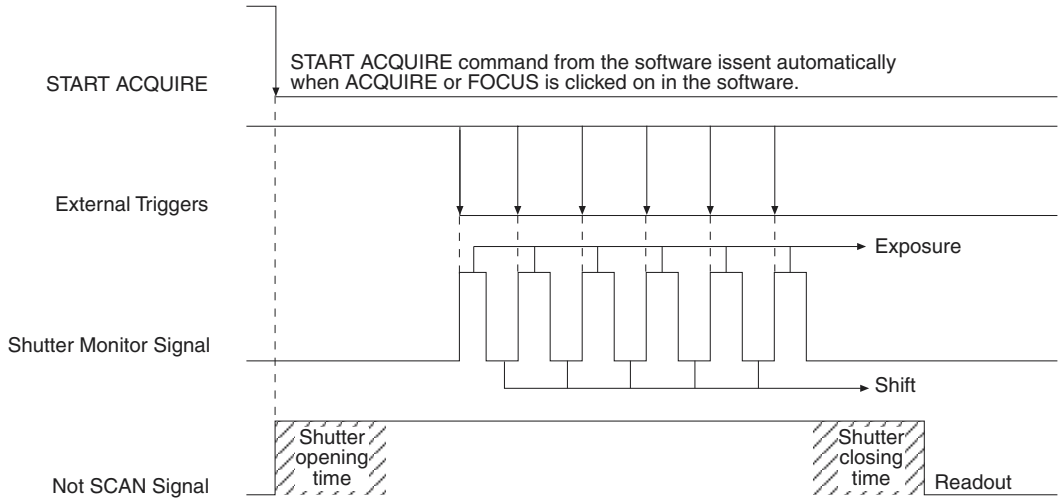

Figure 61. Multiple Trigger Timing Diagram

Appendix D
Virtual Chip Mode

Introduction

Virtual Chip mode (a WinView/32 option) is a special fast-acquisition technique that allows frame rates in excess of 100 fps to be obtained. For the Virtual Chip selection to be present, it is necessary that:

- the system be a 1 MHz MicroMAX,
- that the camera have a frame transfer chip (MicroMAX:512BFT) and,
- that the file Wxvchip.opt be present in the same directory as the executable WinView/32 program. *Contact Technical Support for information regarding the availability of Wxvchip.opt.*

This method of data acquisition requires that the chip be masked as shown in Figure 62. Masking can be achieved by applying a mechanical or optical mask or by positioning a bright image at the ROI against a dark background on the remainder of the array.

In operation, images are continually piped down the CCD at extraordinarily high frames per second (FPS). The mini-frame transfer region is defined by an ROI as illustrated in Figure 62. The charge from this ROI is shifted under the frame-transfer mask, followed by a readout cycle of an ROI-sized region under the mask. Since the ROI is far from the serial register, the stored image is just shifted repeatedly with the readout and the first few images collected will not contain useful data. After the readout period, the next frame is shifted under the mask and another ROI sized frame is read out. The net result is a series of images, separated by spacer regions, streaming up the CCD under the mask.

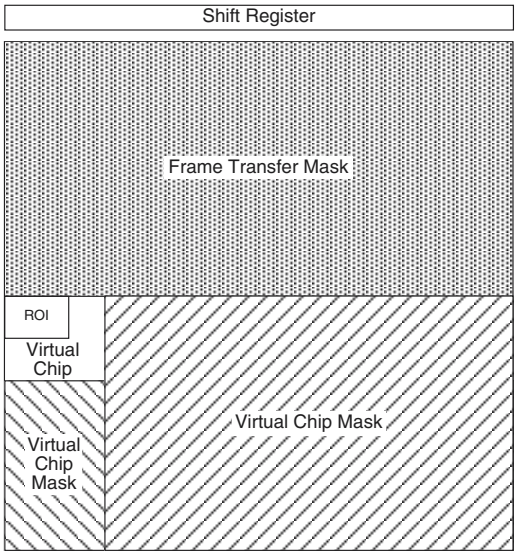

Figure 62. Virtual Chip Functional Diagram

The table below shows the minimum exposure time per frame (msec/Frame) and the number of frames per second (FPS) for several ROIs. Note that these numbers are provided for the 1 MHz and the 100 kHz readout rates.

ROI	1 MHz		100 kHz	
	(msec/Frame)	(FPS)	(msec/Frame)	(FPS)
164 x 164	29.8	33.6	287	3.5
96 x 96	10.9	91.7	102	9.8
84 x 84	8.65	115	79.8	12.5
64 x 64	5.26	190	47.6	21.0
56 x 56	4.22	237	37.4	36.7
47 x 47	3.08	324	26.9	37.2
36 x 36	1.97	507	16.6	60.2
30 x 30	1.51	662	12.2	82.0

Table 13. MicroMAX:512BFT: Virtual Chip Size, Exposure Time, and Frames per Second

Virtual Chip Setup

Introduction

If the Virtual Chip mode option has been installed, both WinView/32 and WinSpec/32 will support this technique. The following procedure covers the basic hardware and software setup for Virtual Chip operation.

Note: The Virtual Chip dialog box is discussed in detail in the next section.

Equipment:

MicroMAX with 512x512FT CCD array

Suitable ST-133

PCI Interface Card and High Speed Serial (TAXI) cable

Suitable Host Computer

Software:

WinView/32, version 2.4 or higher

WXvchip.opt installed in the same directory as the executable WinView/32 program

Assumptions:

- You are familiar with the WinView/32 software and have read the hardware manuals.
- Masking is for a 47x47 pixel Virtual Chip with its origin at 1,1.

System Connection Diagram:

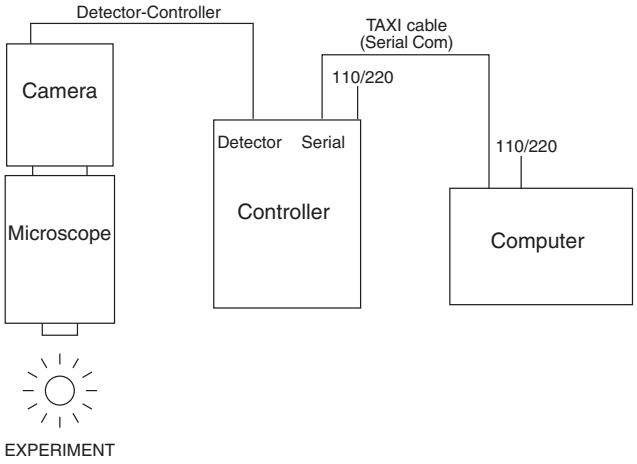

Figure 63. System Diagram

Procedure:

1. Verify that the power is **OFF** for **ALL** system components (including the host computer).
2. Verify that the correct line voltages have been selected and that the correct fuses have been installed in the ST-133.
3. Connect the TAXI cable to the interface card at the host computer and to the **Serial Com** connector at the rear of the Controller. Tighten down the locking screws.
4. Connect the **Camera-Controller** cable to the **Detector** connector on the rear of the Controller and to the **Detector** connector at the rear of the camera. Tighten down the locking screws.
5. If it has not been installed already, connect a line cord from the Power Input module on the back of the Controller to a suitable AC power source.
6. Turn on the Controller.
7. Turn on the host computer and select the WinView/32 icon.
8. From the **Setup** menu, select **Hardware**, and enter the following settings:

   Controller/CCD tab card

   - **Controller:** MicroMAX
   - **Controller Version:** 5
   - **CCD Type:** appropriate frame transfer array (EEV 512x512FT, for this procedure)

- **Shutter Type:** None
- **LOGIC OUT Output:** Shutter
- **Readout Mode:** Frame Transfer

Interface tab card

- **Type:** the appropriate interface card. For this procedure, the selection is High Speed PCI.

Cleans/Skips tab card

- **Number of Cleans:** 1
- **Number of Strips per Clean:** 512
- **Minimum Block Size:** 2
- **Number of Blocks:** 5

9. From the **Acquisition** menu, select **Experiment Setup** and enter the following settings:

Main tab card

- **Exposure Time:** Enter a value. The exposure time can either be greater than the readout time or it can be equal to the readout time. If you want an exposure time > readout time, enter a value larger than the readout time calculated when the virtual chip definition was downloaded. If you want an exposure time = readout time, enter 000 sec.
- **Number of Images:** Enter the desired number of images.
- **Use Region of Interest**
- **Accumulations:** 1

ADC tab card

- **Type:** FAST

ROI Setup tab card: Make no changes to the settings on this tab card unless you have re-enabled Normal Operating Mode. ROI setup for Virtual Chip (High Speed Mode) is performed through the Virtual Chip dialog box.

10. From the **Setup** menu, select **Virtual Chip**, and enter the following settings:

- **High Speed Mode Enabled**
- **Virtual Chip Definition:** The settings below assume a 47x47 pixel virtual chip. The X and Y dimensions are established by the external mask. The virtual chip is fully flexible in the X direction. However, the set of choices for the Y-dimension has been pre- selected for optimal performance. Note that the origin point that Roper Scientific uses for a CCD array is 1,1.
  - **Chip Y Dimension:** 47. Select this dimension from the drop down list.
  - **Chip X Dimension:** 47. Enter this dimension manually.

11. Click on the **Load Default Values** button. This enters the default ROI values. These values are: Start pixels of 1,1; End pixels based on the Chip Y and Chip X dimensions; and Groups of 1.

    - **Region of Interest:** The settings below assume a 47x47 pixel ROI (i.e., the entire virtual chip). An ROI that is a subset of the virtual chip can be defined.

      X Start: 1 **Y Start:** 1

      X End: 47 **Y End:** 47

      X Group: 1 **Y Group:** 1

    - Click on the **Download Virtual Chip Definition** button. This will download the definition, set up the ROI, and calculate the readout time.

    - Observe the calculated readout time. If you need a shorter period, change the settings (for example, enter a smaller Y-dimension or use binning in the Y-direction) and click on the **Download Virtual Chip Definition** button again.

    - Click on **Close**.

12. From the **Setup** menu, select **Environment**.

    Note: When setting up for focusing, the number of **Frames/Interrupt** should be left at 1.

    - **DMA Buffer (Mb):** By default, the buffer size is 8 Mb. Using the following formula, calculate the amount of DMA memory required:
      X × Y × #Frames × (2 bytes/pixel).
      For example, the buffer size required for a **47**x**47** virtual array acquiring 1000 frames would be **47 × 47 × 1000 frames × (2 bytes/pixel) = 4.4 Mb**. If the calculated value is greater than 8 Mb, enter the appropriate size.

      Note: This value is not enabled until you restart your computer.

    - **Frames/Interrupt:** If the number of frames is greater than 256 (the pre-programmed slot limit for a PCI card), increase the number of **Frames/Interrupt** value. Use the formula **#Frames/256** and round the result to the next highest integer to calculate that value. For example, 1000 frames/256 will result in 3.9, so enter 4.

      Note: This value should be 1 for **Focus** mode.

13. Click on **OK** after you have finished entering the Environment settings.

14. Place a suitable target in front of the camera and click on **Focus** to verify that the camera is seeing the target.

15. Make any focusing, gain, or other adjustments necessary to fine-tune the image.

16. Stop running in **Focus** mode.

17. Now click on **Acquire**.

Experimental Timing

Triggering can be achieved through the software via the **Software Trigger** timing mode (selectable on the **Experiment Setup** dialog box, **Timing Mode** tab page) or it can be achieved via the **Ext Sync** input on the rear of the camera. Triggering from the **Ext Sync** input allows you to acquire a single image per TTL pulse. If **Software Trigger** has been selected, back-to-back collection of the requested number of images will be initiated when **Acquire** is selected: no further TTL trigger input is required.

Virtual Chip dialog box

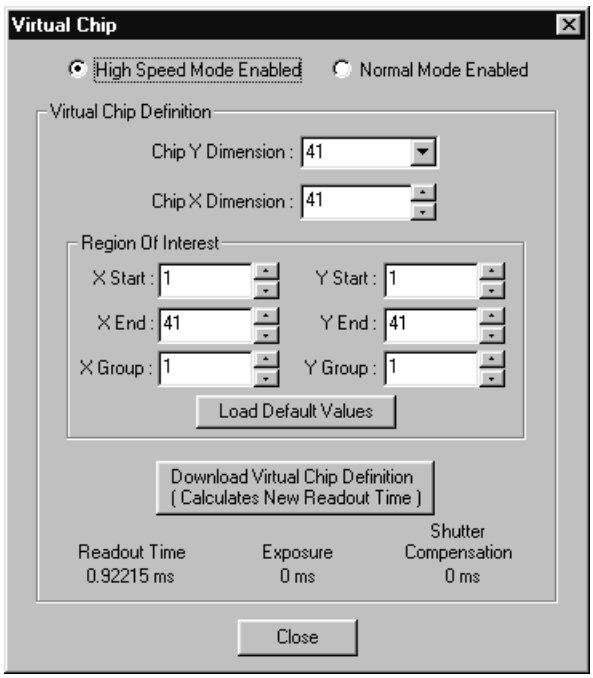

Figure 64. Virtual Chip dialog box.

Clicking **Virtual Chip** on the **Setup** menu displays the **Virtual Chip** dialog box. When the **High Speed Mode Enabled** radio button is selected, all of the fields and buttons on the box will be activated as shown in Figure 64.

Mode: Radio buttons allow the choice of **High Speed Mode Enabled** and **Normal Mode Enabled**. In the normal mode, the external masks would ordinarily be withdrawn, allowing normal frame-transfer operation. All of the parameter settings on the screen are grayed out if **Normal Mode Enabled** is selected. When **High Speed Mode Enabled** is selected, high speed frame rates using the virtual chip can be obtained as described above.

Chip Y Dimension: This is the Y range established by the external mask.

Chip X Dimension: This is the X range established by the external mask.

ROI: The X and Y Start, End and Binning (Group) values can be entered. The ROI can be as large as the virtual chip area established by the external mask or a subregion.

Load Default Values: Fills in the region of interest X and Y End values based on the Chip X and Y Dimension entries. By default, the ROI origin is at 1,1 and the Group values are both 1.

Download Virtual Chip Definition: Sends the virtual chip parameter values to the controller's non-volatile memory. If a virtual chip definition is already stored there, you will be given an overwrite warning.

Readout Time: Reported readout time that will result with the current virtual-chip parameter values.

Exposure Time: Reported current exposure time that will result with the value entered in the **Experiment Setup** dialog box.

Shutter Compensation Time: Reported value; depends on selected shutter type.

Close: Closes Virtual Chip dialog box.

Tips

- If mechanical masking is used, the mask can be a static one (fixed dimensions) in which case, multiple masks should be made to accommodate a variety of imaging conditions. Alternatively, a more flexible mask can be manufactured by taking two thin metal sheets with a square hole the size of the exposed region of the CCD cut in the center. This would be 512 × 512 pixels at 15 microns per pixel = 7.68 mm × 7.68 mm for the MicroMAX. These masks should be anodized black to prevent reflections in the optical system and they should be very flat. These two sheets can then be slid relative to one another to achieve any rectangular shape required. The sheets should be placed flat in the optical plane and their openings should be centered on the optical axis. Ideally they should be able to move with an accuracy of 2-3 pixels per step (30-45 microns) in the X and Y directions.

  Consult the factory for off-the-shelf optical masking accessories

- Running the camera in Free Run mode with 0.0 msec exposure time will result in the fastest acquisition time. Under these conditions, the acquisition time is limited by the readout time of the ROI (exposure time ≡ readout time).

- When you return the system to "Normal" chip mode (radio button on **Virtual Chip** dialog box), you should also open the **Experiment Setup** dialog box at the ROI Setup tab card and click on the **ClearAll** button to clear the ROI setup downloaded for Virtual Chip operation.

- If frame acquisition appears to be slow in Focus mode, check the **Frames/Interrupt** value on the **Environment** dialog box and reset the value to 1 if it is greater than 1.

- When processing large stacks of data, you may want to use a third-party scientific image processing package.

- Due to CCD design, you may see some edge artifacts when acquiring data from the entire virtual chip. Crop these artifacts by defining an ROI that is slightly smaller than the virtual chip dimensions.

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Appendix E
Repumping the Vacuum

Introduction

Round head cameras are normally shipped with a vacuum level of ~10 mTorr or better to assure proper cooling performance and to prevent condensation from collecting on the CCD. This condensation obscures or interferes with optical signals, and can leave behind harmful contaminants. In time, the vacuum level could deteriorate to where achieving temperature lock will no longer be possible. If this happens, it will be necessary to repump the vacuum to restore normal cooling performance. Instructions for repumping the vacuum for a 1 MHz or 100kHz/1MHz round head camera are included in this appendix. Contact the factory for instructions if you have a 5 MHz camera that you believe may need to be repumped.

CAUTION

Do not repump the vacuum until system operation has been verified. The system must be functioning properly before you can determine that repumping is necessary. Causes other than vacuum loss could make it impossible to achieve temperature lock *(see Cooling Troubleshooting on page 91).*

Notes:

1. To minimize outgassing, all Roper Scientific detectors are vacuum baked at the factory. Nevertheless, new detectors will experience a higher outgassing rate than detectors that have been in operation for several months, and are more likely to require repumping.
2. Users can request a nitrogen back-filled detector, which prevents condensation without the need for pumping. If your detector was prepared this way at the factory, no attempts at pumping should be made.

WARNING

Operating the camera without proper evacuation may result in serious or irreversible damage from condensation. Do not operate the camera unless the vacuum chamber is either evacuated or filled with a dry, non-corrosive gas (e.g. dry nitrogen).

Requirements

- A laboratory-type vacuum pump capable of achieving 10 mTorr or lower.

CAUTION

Your vacuum system *must* have a trap (ideally cryogenic) placed between the camera and the pump to prevent contamination due to backstreaming from the pump.

- Special vacuum pumpdown connector, as shown in Figure 65.

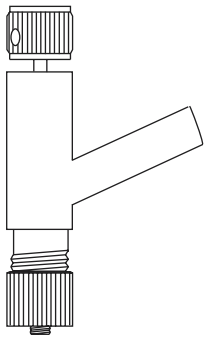

Figure 65. Vacuum Connector Required for Pumping

- Phillips screwdriver and a 3/16" nut driver, required to remove the back plate from the camera.

Vacuum Pumpdown Procedure

The instructions that follow are for a 1 MHz or 100kHz/1 MHz round head camera only. Contact the factory if you have a 5 MHz round head camera that you think may need to be repumped

1. Remove the back cover of the camera (see Figure 66). It is secured by four Phillips-head screws and by the two connector slide-latch posts, which can be removed using a 3/16" nut driver.

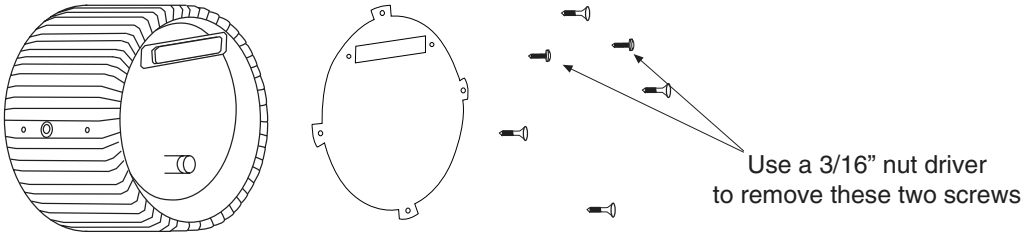

Figure 66. Removing the Back Panel

2. Push the Vacuum Connector onto the vacuum port on the back of the camera (see Figure 67). Tighten the bottom knurled ring (the one closest to the camera body).
3. Connect the vacuum system to the open tube and begin pumping. The vacuum equipment should first be pumped down to a reasonable level before the camera vacuum is opened.
4. After a reasonable vacuum level is reached (~20 mTorr), turn the top knob of the Vacuum Connector clockwise a few turns. While holding the body of the connector, pull up on the top knurled knob until it stops (see Figure 68). This opens the camera to the vacuum system, and a change in vacuum pressure in the system should be observed.
5. Pump down to 10 mTorr or as close as possible. Overnight pumping may be required.
6. When this level has been achieved, push the top knob all the way in until it stops. The vacuum block is now sealed. Turn the same knob counterclockwise several turns, to free the plug from the Vacuum Connector.

7. Remove the vacuum system from the Vacuum Connector. While turning the top knob counterclockwise, remove the Vacuum Connector from the camera. Replace the back cover.

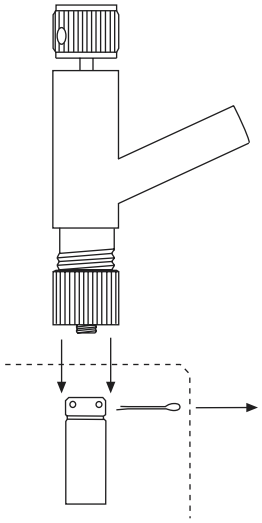

Figure 67. Attaching the Vacuum Connector

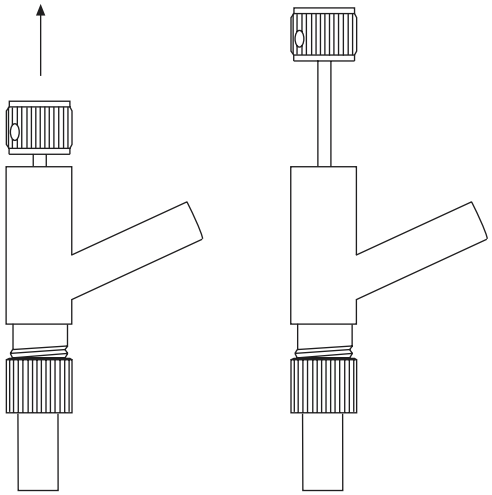

Figure 68. Opening the Camera to the Vacuum System

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Warranty & Service

Limited Warranty: Roper Scientific Analytical Instrumentation

Roper Scientific, Inc. makes the following limited warranties. These limited warranties extend to the original purchaser only and no other purchaser or transferee.

Limited One (1) Year Warranty

Roper Scientific warrants this product against defects in materials or workmanship for a period 1 year after the date of original invoice. During this period, Roper Scientific will repair a defective product or part, without charge to you. You must deliver the entire product to the Roper Scientific factory or, at our option, a factory authorized service center. You are responsible for all transportation and insurance charges to return the product to the service center and Roper Scientific will be responsible for all transportation charges and insurance to return the product to you. International customers should contact your local manufacturer's representative/distributor for repair information and assistance or visit our technical support page at www.roperscientific.com.

Shutter Warranty

Roper Scientific warrants the standard, factory-installed shutter of all our products that incorporate an integrated shutter for a period of twelve (12) months. This warranty applies to the standard shutter installed in the camera system at the time of manufacture. *Non-standard shutters, SPR (special product request) shutters, and third-party shutter drive equipment carry no warranty expressed or implied.* Roper Scientific will supply, at no cost to the customer, up to one (1) replacement shutter during the warranty period. Roper Scientific will, at Roper Scientific's option, either ship a ready-to-install shutter to the customer site for installation by the customer according to the instructions in the product User Manual or arrange with the customer to return the camera system (or portion of the camera system) to the factory (or factory authorized service center) for shutter replacement by a factory-authorized agent. Responsibility for transportation and insurance charges is described above.

Sealed Chamber Integrity Warranty

Roper Scientific warrants the sealed chamber integrity of all our products for a period of twenty-four (24) months. *Open chamber products carry no warranty to the CCD imaging device expressed or implied.*

Vacuum Integrity Warranty

Roper Scientific warrants the vacuum integrity of all our products for a period of twenty-four (24) months during which we guarantee the detector head will maintain the factory-set operating temperature without the requirement for customer pumping.

Image Intensifier Detector Warranty

All image intensifiers by nature are susceptible to Phosphor and/or Photocathode burn (physical) damage when exposed to high intensity light. Roper Scientific warrants, with the exception of an image intensifier that is found to have a Phosphor and/or

Photocathode burn damage (which carries no warranty expressed or implied), all image-intensified products for a period of 1 year after the date of the original invoice. *See the Limited One (1) year warranty terms and conditions above.*

X-Ray Detector Warranty

Roper Scientific warrants, with the exception of the CCD imaging device and fiber optic assembly damaged due to x-ray (which carry no warranty expressed or implied), all x-ray products for a period of 1 year after the date of the original invoice. *See the Limited One (1) year warranty terms and conditions above.*

Software Warranty

Roper Scientific warrants the software discs are free from defects in materials and workmanship under normal use for a period of one (1) year from date of original invoice. Roper Scientific does not warrant that the function of the software will meet your requirements or that operation will be uninterrupted or error free. You assume responsibility for selecting the software to achieve your intended results and for the use and results obtained from the software. In addition, during the 12-month limited warranty the original purchaser is also entitled to receive free of charge minor version upgrades. A minor version upgrade is defined as an upgrade within the same version release (i.e., 2.4.1 to 2.4.2 and not 2.4. to 2.5). Minor version upgrades supplied free of charge will be in the form of a download from the Internet. Those customers who do not have access to the Internet may obtain the minor version upgrades on a CD-ROM from our factory for an incidental shipping and handling charge. *See contacting us in the" Your Responsibility" section of this warranty for more information.*

Owner's Manual and Troubleshooting

You should read the owner's manual thoroughly before operating this product. In the unlikely event that you should encounter operation difficulties, the owner's manual should be consulted before calling the factory for support. If you have consulted the owner's manual and the problem still persists, please contact the appropriate factory for support. *See contacting us in the "Your Responsibility" section of this warranty for more information.*

Your Responsibility

The above warranties are subject to the following conditions:

1. You must retain your bill of sale (invoice) or provide other proof of purchase.
2. You must notify the factory service center within the first thirty (30) days after you have taken delivery of a defective product or part. With the exception of customers who claim a "technical issue" with the operation of the product or part, all invoices must be paid in accordance with the terms of sale. Failure to pay invoices when due may result in the interruption of your one (1) year limited warranty and/or any other warranty expressed or implied.
3. All warranty service must be made by the factory or, at our option, an authorized service center.
4. Before products or parts can be returned for service the customer must contact the factory and receive a return authorization number (RMA). Products or parts returned for service without a return authorization will be sent back freight collect.
5. These warranties are effective only if purchased from the factory or one of our authorized manufacturer's representatives or distributors.

6. Unless specified as part of the original purchase agreement, Roper Scientific is not responsible for installation, setup, or disassembly at the customer's location.
7. Warranties extend only to defects in materials or workmanship as limited above and do not extend to any product or parts which have been lost or discarded by you; to damage to products or parts caused by misuse in violation of instructions furnished by us; or to units which have had serial numbers removed altered, defaced, or rendered illegible.
8. At your option after the warranty period has expired, you may contact the factory for repair information and extended warranty plans.
9. Physically damaged units or units that have been modified by a customer are not acceptable for repair in or out of warranty and will be returned as received.
10. All warranties implied by state law or international laws, including the implied warranties of merchantability and fitness for a particular purpose, are expressly limited to the duration of the limited warranties set forth above. With the exception of any warranties implied by state law or international laws, as hereby limited, the forgoing warranty is exclusive and in lieu of all other warranties, guarantees, agreements, and similar obligations of manufacturer or seller with respect to the repair or replacement of any parts. In no event shall Roper Scientific liability exceed the cost of the repair or replacement of the defective product or part.
11. This warranty gives you specific legal rights and you may also have other rights that may vary from state to state and internationally from country to country. Some states and countries do not allow limitations on how long an implied warranty lasts, when an action may be brought, or the exclusion or limitation of incidental or consequential damages, so the above provisions may not apply to you.
12. When contacting us for technical support or service assistance, please refer to the factory of purchase, contact your manufacturer's representative or reseller, or visit our technical support page at www.roperscientific.com.

Contact Information

Roper Scientific's manufacturing facility for this product is located at the following address:

Roper Scientific
3660 Quakerbridge Road
Trenton, NJ 08619 (USA)

Tel: 609-587-9797
Fax: 609-587-1970

Technical Support E-mail: techsupport@roperscientific.com.

For technical support and service outside the United States, see our web page at www.roperscientific.com. An up-to-date list of addresses, telephone numbers, and e-mail addresses of Roper Scientific's overseas offices and representatives is maintained on the web page.

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Index

#-B

64-pin DIN connector 82, 96
A/D converters
  dual 62
  specifications 99
AC power requirements 18
Actual exposure time 43, 46
Air-circulation requirement 81
Analog channels 62
Analog/Control module 82, 83
Applications 11
Back-filled 119
Background DC level 52
Background subtraction 40
Back-plane 82
Baseline signal 28, 52
  ST-133 zero adjustment 84
Binning
  computer memory burden 60
  hardware 59, 61
    restrictions due to well capacity 62
  readout time 60
  resolution loss 60
  software 62
    effect on S/N ratio 62
    high light level measurements 62
    shot-noise limited measurements 62
Blooming 52
Bottom clamps, table of 22

C

Cables 17
Camera
  back panel 80
  connector 80
  fan 80
  introduction to 9
  mounting considerations
    1/4" x 20 UNC threaded holes 19
    orientation constraints 19
    use oF-mounting bracket for security 19
Cautions
  baseline signal shift 28, 89
  IR contamination 23
  need for trap in vacuum system 119
Cautions (cont.)
  system verification 119
  zero adjustments 84
CCD arrays
  blooming 52
  dark charge effects 52
  functions performed 49
  maximum on-chip integration 52
  readout of 53, 56
  readout theory 53
  shift register 53
  shutter function 50
  signal-to-noise ratio vs on chip integration time 52
  theory of operation 49
  well capacity 52
    table of 62
CCIR 84
Cleaning
  controller and detector 14
  optics 14
C-mount 21
  assembly 21
  lens installation and removal 19
  support recommendations 21
Cold finger 79
Collection area 49
Compensation time
  shutter 50
Composite video output 84
Connectors
  ST-133, AUX Output 84
  ST-133, Detector 84
  ST-133, External Sync 84
  ST-133, NOTREADY 84
  ST-133, NOTSCAN 84
  ST-133, Serial COM 84
  ST-133, TTL In/Out 84
  ST-133, Video Output 84
Contact information 125
Continuous Cleans. 42
Controller
  dimensioned outline drawing 101
  modules 82
Cooling 80
Cooling and vacuum 91

C-type lens mount 19

D-E

Dark charge 42
  definition of 52
  dynamic range 52
  pattern 52
  temperature dependence 52
  typical values 52
Dark current 52
Data smearing 50
Detector
  cooling 28
Detector connector (ST-133) 84
Diagnostic Instruments Bottom Clamp 21
Diagnostic Instruments Relay Lens 21, 35
DIF camera 65
  background subtraction 72
  EEC timing mode 70
  ESABI timing mode 71
  Flatfield correction 73
  Free Run timing mode 66
  IEC timing mode 68
  laboratory illumination 72
  Mask Throughput correction 73
  timing modes 66
  Tips and Tricks 72
Digitization 62
DMA buffer 115
Dual A/D converters 62
Dual Image Feature camera *See* DIF camera
Dynamic range 52
EEC timing mode 70
EIA 84
Electronics enclosure 80
EMF spike 27
Environmental conditions 13
ESABI timing mode 71
Exposure 50
  image intensifier 51
  shutter 50
Exposure and Readout 49
Exposure time 38
  actual 43, 46
  programmed 43, 46
External shutter 85
External Sync
  background subtraction 40
  dark charge accumulation 42
  frame-transfer 43
  input pulse 40
  overlapped mode 46
  shutter synchronization 40
  timing 40
External synchronization 40

F

Fan
  camera 80
  ST-133 controller 85
Field of view 29
  formula for 29
First images procedure 32
First Light
  spectroscopy 31
Fluorescence microscopy 20
F-mount
  assembly of in microscopy 22
  lensinstallation and removal 19
  nose-up operation 19
  port selection 22
  suitability for microscopy 22
  support recommendations 22
Focusing 35
  aperture adjustment 20
  composite video output 29
Frame transfer
  CCD requirements 43
  external sync 43
  free run 43
  mode 43
  readout 55
  smearing 51
  timing 43
Frames/Interrupt 115
Free Run
  DIF camera 66
  experiments best suited for 38
  Frame transfer 43
  Overlapped mode 46
  timing 38
  timing diagram 40
  timing flow-chart 40
Full frame readout 53
Full Speed (Asynchronous) mode 37
Full Speed (Synchronous) mode 37
  data acquisition 37
  image update lag 37
Fuse replacement, ST-133 89

G-L

Gated operation
  smearing 50
Grounding and safety 13
Hardware binning 59, 61
Humidity, in vacuum enclosure 28, 89
I/O Address conflicts 92
IEC timing mode 68

Image intensifier 51
Imaging field of view 29
Interface card
  driver installation 24
  PCI 24
    High Speed PCI 24
    PCI(Timer) 24
  troubleshooting 92
Interface Control module 82, 83
Interline CCDs 46
  smearing 52
Interrupt conflicts 92
IR
  CCD sensitivity to 23
IR blockers 23
ISA interface card
  driver installation 90
  I/O address, DMA channel, and interrupt level 93
  installation 25
Latency 42
LCI 51
Lens Coupled Intensifier (LCI) 51
Lens mount housing 80
Lens mounting 19
Lenses
  installation and removal 19
Line voltage selection (ST-133)
  procedure 89
  selector drum 18

M

Macintosh II support 99
Memory requirement 11
MicroMAX system
  applications 11
  camera 9
  camera cooling system 10
  CCD array 10
  components of 17
  controller
    data conversion 10
    data transfer 11
    modular design 11
    readout flexibility 11
  overview 9
MicroMAX:1300YHS 10
MicroMAX:1300YHS-DIF 10
MicroMAX:782YHS 10
Microscope
  mounting 20
    C-mount 21
    F-mount 21
Microscopy 20
  arc lamp EMF spike damage warning 27
  focusing 35
  IR blockers 23
  light throughput 20
  Light throughput 20
  Magnification 20
  Numerical Aperture (NA) 20
  parfocality 35
  Transmission efficiency 20
  Xenon or Hg lamp EMF spike 27
Monitor requirement 11
Mounting to a microscope
  C-mount 21
  F-mount 21
Mouse requirement 12

N-O

Noise
  low-noise readout 10
Non-Overlapped operation 45
  example 57
NOT READY connector 84
NOTSCAN
  signal 84
  timing 51
Outgassing 119
Outline drawing
  controller 101
  rectangular head camera 102, 103
  round head camera 104, 106
Overlapped operation 45
  example 56
  External Sync 46
  Free Run 46
  readout mode 46

P-R

Pan function 30
Parfocality 35
PCI serial interface card 17
  diagnostics software 93
  driver installation 24
  non-conforming peripheral cards 94
Peltier effect thermoelectric cooler 27
Peltier-effect cooler 79
Photodamage 20
Photodiodes 49
Plug-in modules, installation and removal 95
Power cord 18
Power input module (ST-133) 85
Power requirements 18
Power switch and indicator 82
Pre Open Shutter mode 41

Procedures
familiarization and checkout 32
First images 32
line voltage selection and line fuse 89
plug-in module installation/removal 96
vacuum pumpdown 120
Programmable Interface connector 75
Programmable TTL interface
connector 84
Quantum efficiency 20
Readout
binning 59, 61
hardware 59, 61
digitization 62
frame transfer 55
rate 62
subsection of array 54, 58, 59
Readout rate
control of 62
precision vs speed tradeoff 62
Readout time 38
Readout times (full frame) for several CCD types
table of 54, 59
Rectangular Head Camera
dimensioned outline drawings 102-103
Relative humidity 13
Relay Lens 21
Resolution
loss of with binning 60
Response latency 42
ROI (Region of Interest) 31
Round Head Camera
dimensioned outline drawings 104-106
RS-170 (EIA) 84

S

S/N ratio 52, 62
Safe (Asynchronous) mode
as used for setting up 37
fast image update 37
missed events 38
Saturation 52
Serial COM connector, ST-133 84
Shift register 53
Shutter
compensation time 38, 50
effect of physical limitations on exposure 51
exposure 50
external 85
SHUTTER MONITOR signal 85
synchronization 84
lifetime 81
Shutter (cont.)
replacement of 81, 96
shutter setting selector (ST-133) 85
signs of failure 81, 96
ST-133 connector 85
Shutter modes
Disable 38
Normal 38
Preopen 38, 41
SHUTTER MONITOR signal 84
Shutter Power connector 85
Signal-to-noise ratio
on-chip integration 52
Smearing 50
frame transfer cameras 51
interline CCDs 52
Smearing in gated operation 50
Software binning 62
Software Trigger 116
Specifications
A/D converter 99
cooling 98
inputs and outputs 98
miscelaneous 100
mounting 98
temperature control 97
Spectroscopy 31
ST-133 Controller
fuse/voltage label 85
power input module 85
zero adjustment 84
Synchronous vs Asynchronous flowchart 39

T

Technical support 125
Temperature
control
problems 91
specifications 97
effect of vacuum deterioration 91
lock 28
LOCK indicator LED 28
operating environment 13
stabilization 28
storage 13
thermal cutout switch 91
thermostated range 28
typical time to achieve lock 28
Temperature Lock LED (ST-133) 84
Termination of video output 30
Thermal cutout switch 91
Timing control 37
Timing modes 37, 38
Continuous Cleans 42

Timing modes (cont.)
DIF camera 66
table of 37
Trap, vacuum 119
Trinocular mount microscopes 20
TTL In/Out connector 84
TTL IN/OUT pin assignments 75

U-V

UV scintillator 80
Vacuum 27
deterioration 91
level required 119
pumpdown connector 17
Vacuum repumping
required equipment
lab-type vacuum pump 119
trap to prevent contaminant backstreaming 119
VCR 30
Video Focus mode 30
Video output
constraints on during data acquisition 30
focusing 29
Virtual Chip mode
setup 112
software option 111
Wxvchip.opt file 111

W

Warnings
cleaning 14
Controller/Camera cable 83
fuse type 89
module installation/removal under power 82, 95
Warnings (cont.)
opening the power input module 89
operation without evacuation or backfill 14
operation without proper evacuation 119
overtightening the module screws 96
power cord polarity 13
protective grounding 13
shutter connect or disconnect under power 81
shutter drive setting 85
touching the CCD array 14
UV scintillator 80
window removal 14
Xenon and Hg arc lamps 27
Warranties
image intensifier detector 123
one year 123
owner's manual and troubleshooting 124
sealed chamber integrity 123
software 124
vacuum integrity 123
x-ray detector 123
your responsibility 124
Website 125
Well 49
Well capacity 52
restrictions on hardware binning 62
table of 62
WinView
ROI 31
Video Focus mode 30
Wxvchip.opt file 111

Z

Zoom function 30

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